FILE COPY
NO. 1-W

CASE FILE
COPY

TECHNICAL NOTES

NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS

No. 678

HYDRODYNAMIC AND AERODYNAMIC TESTS OF FOUR MODELS OF OUTBOARD FLOATS (N.A.C.A. MODELS 51-A, 51-B, 51-C, AND 51-D)

By John R. Dawson and Edwin P. Hartman
Langley Memorial Aeronautical Laboratory

Washington
December 1938

NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS

TECHNICAL NOTE NO. 678

HYDRODYNAMIC AND AERODYNAMIC TESTS OF FOUR MODELS OF OUTBOARD FLOATS (N.A.C.A. MODELS 51-A, 51-B, 51-C, AND 51-D)

By John R. Dawson and Edwin P. Hartman

SUMMARY

Four models of outboard floats (N.A.C.A. models 51-A, 51-B, 51-C, and 51-D) were tested in the N.A.C.A. tank to determine their hydrodynamic characteristics and in the 20-foot wind tunnel to determine their aerodynamic drag. The results of the tests, together with comparisons of them, are presented in the form of charts. From the comparisons, the order of merit of the models is estimated for each factor considered.

The best compromise between the various factors seems to be given by model 51-D. This model is the only one in the series with a transverse step.

INTRODUCTION

The conventional single-float or single-hull seaplane is not inherently stable about its longitudinal axis when operating on the water at low speeds or when at rest, and an external means for maintaining lateral stability on the water must be provided. The usual method of obtaining the required lateral stability is the use of stub-wing stabilizers, or side floats. Side floats are usually of two types, inboard and outboard, according to their position relative to the main hull or float. In practice, there is a more specific difference between the two types of side float because it is customary to place outboard floats so that they are clear of the water when the main float of the seaplane is on an even keel; whereas inboard floats usually are set so that, when the seaplane is at rest, both inboard floats have a small amount of displacement and tend to maintain the craft on an even keel.

The actual method to be used for providing lateral stability on the water will be selected by the designer to suit his conditions. Sometimes the choice is the result of a detailed design study and, in order to make such a study, data on both side floats and stub-wing stabilizers are definitely needed. Numerous requests from manufacturers and from the Bureau of Aeronautics, Navy Department, have caused the N.A.C.A. to institute a research program in which it is intended to include both tank and wind-tunnel tests on inboard floats, outboard floats, and stub-wing stabilizers.

This paper presents the results obtained from tests conducted in the N.A.C.A. tank and the 20-foot wind tunnel at Langley Field, Va., of four models of outboard floats (N.A.C.A. models 51-A, 51-B, 51-C, and 51-D). The tests were made in March and April 1936.

MODELS

Three of the models selected for testing were made from lines furnished by the Bureau of Aeronautics, Navy Department. The lines of the fourth model were prepared at the N.A.C.A. tank, but the model resembles a type sometimes used in Europe. The lines of the models are shown in figures 1 to 4 and the offsets are given in tables I to IV.

Model 51-A is a model of the outboard float of the Navy PH-1 flying boat. This float has fairly simple lines, the dead rise is moderate, and the stern is pointed in plan form.

Model 51-B is a model of the outboard float of the Navy 03U-3 single-float seaplane. Apparently, this float was particularly designed to have low air drag as both the bow and the deck are rounded. It is similar to model 51-A in plan form but has greater dead rise.

Model 51-C was designed at the N.A.C.A. tank. It has both rounded bow and deck but tapers in profile instead of in plan form so that the center of volume is rather far forward. Because of its wide stern and low dead rise, this model has an excellent planing surface.

Model 51-D is a model of the Bureau of Aeronautics Mark XI float and is the only one of the floats tested that

has a step. The use of the step permits a large planing area in combination with a pointed stern and results in a comparatively shallow float.

The models were of approximately the same volume, which was chosen to permit testing the models with loads corresponding to the submerged displacements. The use of larger models would have required alterations in the existing testing apparatus in order to measure the large resistances, and extensive equipment would have been necessary to prevent the salt-water spray thrown up by the models from reaching all parts of the apparatus and the towing carriage.

The models were made of wood, sanded, painted, and rubbed in the usual manner.

APPARATUS AND PROCEDURE

Tank Tests

The N.A.C.A. tank and its carriage are described in reference 1. The towing gear used in these tests is described in reference 2.

The method followed in testing the models was similar to the "general test" method in that resistance, draft, and trimming moment were measured at selected constant speeds, loads, and trims. In the present tests, however, the loads were selected to cover a range between zero and a load equal to the submerged displacement of the model at rest, except in the case of low trims at certain speeds where the spray thrown by the model was so great that it prohibited testing at the higher loads. The range of trims was made great enough to include the practicable range of trims for seaplanes plus the practicable range of outboard-float settings.

All tests were made with the models on an even keel. If the outboard floats are rigged so that when they touch the water they are heeled slightly inboard, then the range of angles of heel for the outboard floats will be so small that the data for zero angle of heel should be substantially correct.

Static data were obtained for the models by applying

the same loads that were used in the tests under way and measuring the draft and trimming moment. These data were obtained for a number of trims.

Wind-Tunnel Tests

The aerodynamic tests of models 51-A, 51-B, 51-C, and 51-D were made in the N.A.C.A. 20-foot wind tunnel described in reference 3. Measurements of air drag were made at speeds ranging from 55 to 104 miles per hour, and the range of pitch angles covered was approximately -15° to 15° measured from the tangent to the after portion of the keel line or, in the case of model 51-D, from the keel line at the step.

The floats were mounted inverted on a short vertical strut in the center of the air stream. The vertical strut was attached to a shielded horizontal supporting bar that was rotatable to provide changes in the angle of pitch. About 6 inches of the thin vertical supporting strut was exposed to the air stream giving a tare drag of about three-fourths pound at 100 miles per hour. The supports and shielding were of metal and were connected in an electrical circuit in such a way that any fouling between the active strut and the shielding would be detected by the lighting of an electric lamp. Figure 5 shows model 51-A mounted in the tunnel.

A horizontal buoyancy correction was made to the drag to compensate for the static-pressure gradient along the center line of the jet. This correction was small, amounting to only one-tenth pound at 100 miles per hour

RESULTS

Tank Tests

The experimental results are presented in nondimensional form by the use of coefficients similar to those used at the N.A.C.A. tank for data from tests of models of seaplane hulls. Inasmuch as the basis for the selection of the size of an outboard float is normally the total volume of the float, the coefficients used in the present tests are based on the cube root of the volume as the characteristic linear dimension instead of the beam (the char-

acteristic dimension used for seaplane hulls). In order to distinguish between the present coefficients and those based on the beam, the letter K will be used instead of the letter C.

The coefficients used in the present tests are defined as follows:

Speed coefficient, $K_V = \frac{V}{g^{1/2} U^{1/6}}$

Load coefficient, $K_\Delta = \frac{\Delta}{wU} = \frac{\Delta}{\Delta_s}$

Resistance coefficient, $K_R = \frac{R}{wU} = \frac{R}{\Delta_s}$

Center-of-pressure coefficient, $K_{c.p.} = \frac{c.p.}{U^{1/3}}$

Draft coefficient, $K_d = \frac{d}{U^{1/3}}$

where V is the speed, f.p.s.

g, the acceleration of gravity, ft./sec.^{2}

U, the volume of the float, cu. ft.

Δ, the load on the float, lb.

w, the specific weight of water, lb./cu. ft. (63.5 lb./cu.ft. for these tests).

Δ_s, the submerged displacement of the float, lb.

R, the water resistance, lb. (including the air drag of the float).

d, the draft, ft. (measured to the lowest point of the float).

c.p., distance to the center of pressure, ft., defined as the distance (measured along the tangent to the keel at the stern) from the stern to the intersection of the resultant

force vector with the tangent to the keel at the stern, except in the case of a float with a step. If the float has a step, the tangent to the keel is taken on the forebody at the step and the distance to the center of pressure is measured from the step instead of the stern.

The reference line for trim is the tangent to the keel at the stern except in the case of a float with a step, in which case the reference line for trim is the tangent to the forebody keel at the step.

The results from the static tests are given in figures 6 to 9, in which the center-of-pressure coefficient and the draft coefficient are plotted against load coefficient with trim as parameter.

The data obtained from tests with the models under way (i.e., resistance, center-of-pressure, and draft coefficients) were plotted against speed coefficient with load coefficient and trim as parameters. Because of their bulk, these plots of original data have been omitted from the present report. Typical data are given in the comparisons shown in figures 10 to 19. These figures will be discussed later.

Wind-Tunnel Tests

The coefficient form used in presenting the final data is defined as follows:

$$C_D = \frac{\text{drag}}{\frac{\rho}{2} V^2 (\text{vol})^{2/3}} \quad \text{or} \quad \frac{D}{q (\text{vol})^{2/3}}$$

where q is the dynamic pressure and $(\text{vol})^{2/3}$ is an area equal to the volume of the float raised to the 2/3 power. As was the case for the hydrodynamic coefficients, it appeared desirable to use volume as a factor in the coefficient form since displacement is such a fundamental factor in float design.

The corrected values of drag were plotted against dynamic pressure but, to reduce the bulk of the report, are not included herein. Drag coefficients were computed for values of drag picked from the curves at a dynamic pressure

corresponding to an air speed of about 80 miles per hour and were plotted against pitch angle as shown in figure 20. This figure provides a comparison of the drag of the four floats at pitch angles measured from the keel lines.

From purely aerodynamic considerations, figure 21 gives a truer picture of the relative cleanness of the four floats than does figure 20. In figure 21, the drag coefficients for each model have been plotted against a pitch angle measured from the position of the float in which its drag is a minimum.

From both hydrodynamic and aerodynamic considerations, the comparison made in figure 20 is perhaps the more practical because the keel line of a float is more likely to have some reference to its setting relative to the wing than its flow line for minimum drag.

DISCUSSION

Comparisons

Basis of comparisons.- The function of outboard floats is to provide righting moments whenever the seaplane heels, whether it is at rest, under way, or drifting. It might then be considered logical to determine which float will give the greatest maximum righting moment under these various conditions. All outboard floats considered for a given design, however, will give the same maximum righting moment at rest because present methods of design use this righting moment as the criterion for the volume of the float. When a seaplane is under way or drifting, comparisons of the maximum righting moments available are of little value because of the lack of information on the righting moments required for these two conditions.

Other factors that should affect the design of an outboard float will, however, be considered as a basis for comparisons between the four models tested. Except in the case of air drag, the comparisons will be made at equal loads for all the floats. This method corresponds to equal righting moments for the seaplane since righting moment is a function of the load on the outboard float.

Another independent variable that will be held constant for purposes of comparison is trim (or angle of pitch).

It is admitted that the reference line chosen for trim was determined primarily from geometrical considerations, but no better reference has been suggested by the results from the tests. The trim for minimum resistance has only minor significance and varies too much to be convenient, the angle of pitch for minimum air drag is too low to warrant consideration, and draft does not consistently show a minimum when plotted against trim.

Angle of heel of seaplane.- For a given righting moment, a minimum angle of heel of the seaplane would be desirable. Draft is the criterion for angle of heel of the seaplane because the angle of heel is a direct function of the draft of the outboard float.

Draft coefficient for the four models at rest at 5° trim is plotted against load coefficient in figure 10. The curves of this figure indicate that greater angles of heel will be reached by a seaplane at rest if model 51-A or 51-B is used than if either model 51-C or 51-D is used except at the maximum righting moment (or $K_{\Delta} = 1.0$) where the curve for model 51-C closely approaches the curves for models 51-A and 51-B. Model 51-D is the best in this respect except at small loads. These static curves are purely a function of the volume distribution of the floats and, if a small angle of heel of the seaplane is desired when the craft is at rest, the depth of the float should be kept relatively small.

The draft coefficients, with the models under way, are compared in figures 11 to 13 in which draft coefficient is plotted against load coefficient for three speed coefficients, a representative trim being chosen for each speed coefficient. In these figures, model 51-C is shown to have the least draft, models 51-D, 51-A, and 51-B having progressively greater drafts.

A further comparison of the drafts of the four models is made in figure 14, which was obtained in the following manner. The volume required for outboard floats for the hypothetical 8,000-pound flying boat of reference 4 was determined on the assumption that the outboard floats were placed 21 feet from the center line of the main hull. The angle of outboard-float setting with respect to the base line of the main hull was assumed to be 4°. The trim curve for the outboard floats was obtained with sufficient accuracy by adding the angle of float setting to the trims taken by the main hull during take-off (fig. 74, reference

4). A load coefficient of 0.6 (468 pounds) was assumed to be applied to one outboard float throughout the take-off range and the draft curve for each of the four models tested was determined from the test data. Figure 14 represents, in effect, the draft that would be reached by the down outboard float if the seaplane were taken off with a rolling moment of 9,800 pound-feet acting continuously without any righting moment other than that supplied by the outboard float.

In figure 15, the drafts from the curves of figure 14 have been converted to angle of heel for the seaplane. These curves of angle of heel have been corrected for the change in draft of the main hull, the drafts for the main hull being determined from figures 21 to 26 of reference 4. Throughout nearly the entire take-off range, model 51-C allows the least angle of heel; models 51-D, 51-A, and 51-B allow progressively greater angles of heel. This order is the same as that obtained in the comparisons of draft coefficients in figures 11 to 13. The order of merit of the models in this respect is the order that might be expected from consideration of the bottoms of the models. Model 51-C undoubtedly has the most effective planing bottom and model 51-D the next best; model 51-A is slightly superior to model 51-B because of a smaller angle of dead rise.

There have been cases in which outboard floats were unintentionally designed so that, when completely submerged while making headway, they resisted efforts to emerge them. Such cases are usually rectified by a redesign of the deck of the floats. Although attempts were made to produce this "sticking" at low speeds with each of the models, no indication of sticking was obtained. It was not practicable to submerge them at very high speeds, however, on account of the excessive spray produced.

An important consideration in selecting outboard floats is the performance when the seaplane is drifting astern. It is necessary that the outboard floats maintain positive righting moment in this condition as well as any other. Because the conditions obtaining when the seaplane is drifting astern with any considerable speed usually include fairly rough water, it is difficult to approximate such conditions in the N.A.C.A. tank with the equipment available at present. It is, however, possible to rate the models in this respect with reasonable accuracy by consideration of their forms. Model 51-D with the afterbody tend-

ing to give dynamic lift when going astern should be the best in this respect. Models 51-A and 51-B with their sharp sterns should have little tendency to "dig in" when making sternway and can be rated about equal. Model 51-C might be entirely unsatisfactory when making sternway because, under this condition, the hydrodynamic forces on the float will probably tend to produce an upsetting moment tending to counteract the righting moment produced by the buoyancy of the float.

Impact loads.- Loads on the structure of the seaplane caused by impact of the outboard floats with the water will naturally be an inverse function of the rate of immersion of outboard floats. The float that allows the least angle of heel of the seaplane will then cause the greatest loads, i.e., model 51-B will cause the least load on the structure, models 51-A, 51-D, and 51-C causing progressively greater loads. Were it not for the energy required to accelerate the surrounding water when an outboard float is rapidly immersed, curves similar to figures 11 to 13 could be used in the manner of variable-spring constants to find the loads imposed on the structure when angular accelerations about the longitudinal axis of the seaplane are encountered. The error in neglecting the acceleration of the water is, however, on the unsafe side and the degree of approximation is uncertain.

Spray.- The spray thrown by the outboard floats is an important though elusive factor that must be considered in design. Unfortunately it is impracticable to attempt to furnish data from which the designer may determine when and where the spray from the outboard floats will strike the rest of the seaplane. The work required to establish the boundaries of the spray for the conditions that might be determining is excessive. Furthermore, the manner in which the spray behaves is not only a function of the shape of the float but also depends on the location of the propellers.

Definite differences in the amount of spray thrown by the models were observed in the tests and the models have been rated accordingly. Model 51-C was the cleanest running model, models 51-D, 51-A, and 51-B throwing progressively more spray. The difference between amounts of spray from models 51-D and 51-A was quite large, but less difference was noted between models 51-C and 51-D or between models 51-A and 51-B. It is difficult to show the actual differences clearly by means of photographs, partly because of

the lack of depth perception; typical photographs taken during the tests are shown in figure 22.

It will be noted that the rating of the models in regard to spray parallels the rating in regard to draft, the model with the least draft throwing the least spray.

Yawing moment of seaplane.- When an outboard float touches the water while the seaplane is under way, a yawing moment, which is a linear function of the water resistance of the outboard float, is developed. Yawing moments are generally undesirable during take-off but, when the seaplane is maneuvering on the water, the yawing moment furnished by the outboard floats is a distinct aid in that it allows short-radius turns at low speeds during which the air rudder is relatively ineffective. For the purposes of this comparison, however, the yawing moment due to the outboard floats will be considered undesirable.

The resistances of the four models are compared in figures 16 to 18 where resistance coefficient is plotted against load coefficient for selected trims and speed coefficients corresponding to those chosen for comparisons of drafts (figs. 11 to 13). A further comparison of resistances is shown in figure 19 where resistance and yawing moment are plotted against speed for the same hypothetical conditions assumed in the comparisons of angle of heel (fig. 15). A study of figures 16 to 19 shows that, although model 51-C consistently has the least resistance, the resistances of the other models do not maintain any consistent order. A more consistent order could probably be obtained if the models were compared on the basis of minimum resistance but the outboard floats will, in general, run at a trim somewhat higher than that required for minimum resistance.

Simplicity of structure.- It is difficult to establish an order of merit in regard to the ease with which the floats can be constructed because variations in plant facilities and methods of the designer will influence this factor. Judging solely from the lines of the models, it appears that model 51-A would be the most easily constructed; models 51-B and 51-C should be about equal in this respect; model 51-D would almost certainly involve the most difficulty in construction.

Air drag.- An examination of the float lines shown in figures 1 to 4 would lead one to expect that model 51-B

would have the lowest drag. It is therefore somewhat surprising to note in figure 20 that, through the most important part of the pitch-angle range (positive angles), model 51-D has a lower drag coefficient than model 51-B. This situation is due to the fact that the keel reference lines, from which both trim and pitch angles were measured, made different angles with the direction of the air flow at minimum drag. If the pitch of each float is assumed to be 0° when in the attitude of minimum drag, the plotted curves of C_D against pitch angle assume a more logical relation, as shown in figure 21. The choice of the reference line from which angles are measured is thus seen to have an important effect on such a comparison.

There seem to be no generally accepted rules in hydrodynamic design regarding the angular setting of outboard floats relative to the wing. It is clear, however, from the appearance of the drag curves in figure 20, that, from aerodynamic considerations, the angle of pitch setting relative to the wing should be made as low as possible.

In figures 1 to 4, showing the profiles of the four models, an arrow has been drawn on each profile to represent the direction of the wind relative to the model when the model is in the attitude of minimum drag. The line of action of the relative wind at minimum drag is such as to minimize the bad effects of the various features of the design. It therefore reveals, to some extent, the features of the design that have the greatest effect on the air drag. On model 51-B (fig. 2) the line lies roughly parallel to the chine, indicating that the chine probably has a predominating effect on the drag of the float. In case of float 51-A (fig. 1) the line is directed between the chine and the deck line at an angle suggesting that the sharp deck line has more effect on the drag than the chine.

On float 51-D (fig. 4), the line of action runs roughly parallel to the chine, indicating the predominating effect of the chine. The step apparently has little influence on the drag of the float because the direction of the flow is not such as to reduce the turbulence behind the step.

Float 51-C (fig. 3) has about the same slope of chine as float 51-D but, owing to its wide beaver-tail shape, has a considerably higher drag at positive angles of attack. The direction of the line of action for float 51-C indicates a tendency to reduce the turbulence caused by the wide after portion of the float.

Summary of comparisons.- The results of the foregoing comparisons are summarized in the following table, which gives the order of merit for each model on the basis of each factor considered. It should be noted that the ratings given are based on general considerations and in any particular design the order might be somewhat changed. The weighting of the factors will vary considerably according to the type of design and to the opinions of the designer.

Model	51-A	51-B	51-C	51-D
Angle of heel:				
At rest	3	3	2	1
Making headway	3	4	1	2
Making sternway	2	2	3	1
Impact loads	2	1	4	3
Spray	3	4	1	2
Yawing moment	2	2	1	2
Structural simplicity	1	2	2	3
Air drag	4	2	3	1

Use of Tank Data

The aerodynamic data indicate that the lowest angle of setting for the outboard floats which will give satisfactory performance on the water is desirable. The data from the tank tests, however, do not suggest a criterion for the minimum permissible float setting. From the information available, the current practice appears to be to set the keel line of the outboard floats approximately parallel to the chord line of the wing or at an angle of from 2° to 6° with respect to the main hull or float. The data regarding spray and angle of heel indicate that model 51-C can be set

at the lowest angle, models 51-D, 51-A, and 51-B, requiring progressively greater angles of float setting. Apparently, observation of the behavior of the outboard floats on the completed seaplane is the best method of determining the minimum satisfactory angle of float setting.

The data are insufficient to permit the determination of design loads for the supports of the outboard floats. The maximum load obtainable from the water resistance of the float would occur when the float is completely submerged at the highest speed at which the seaplane is on the water but the resistance under such conditions would be so large that it would be entirely uneconomical to attempt to design for it. Supports for side floats are customarily designed so that the supports will fail before the main structure of the wing is damaged. Because of the large load-carrying capacity of the outboard floats at high speeds, complete submergence of the floats in this region should be rare. In view of these considerations, tests with outboard-float models submerged at speeds corresponding to full-size take-off speeds appear to be unwarranted.

Float and Hull Design from Aerodynamic Considerations

The use of airship-form bodies for hulls and floats has, for hydrodynamic reasons, been found impracticable. Chines and steps seem to be necessary parts of such bodies in spite of their bad aerodynamic effects. It should be pointed out, however, that floats and hulls are often designed in such a manner that the bad effects of the chines are unnecessarily great.

It has been shown in reference 5 that the minimum drag of a streamline body with square cross sections, such as the one in figure 23(b), is but little greater than the drag of a streamline body of circular cross sections (fig. 23(a)) having an equal cross-sectional area. The slightly greater drag of the square body was attributed to skin friction as the square body had a larger surface area. The form drags of the two were apparently very nearly the same despite the sharp corners of the square body. The air as it meets the nose of the square-section body is forced to accelerate uniformly along all four sides so there is no tendency for flow across the sharp corners. The air flow forms a symmetrical pattern about the corner lines and they do not affect the form drag except at angles of pitch and yaw other than zero.

For comparison, consider the air flow about a boat-shaped body (fig. 23(c)), which is streamlined in one view but rectangular in the other. Here the air is forced to accelerate in only two directions and a pressure gradient is formed tending to cause the air to flow across the sharp edges, thus producing turbulence and added drag. A quantitative indication of the extent of the bad effect of sharp corners across which pressure gradients are operating is given in reference 6. In this reference are given the drag coefficients for a flying-boat hull with a sharp-edge flat deck and for the same hull after the deck corners had been given a generous radius of curvature. The drag coefficient for the hull with the sharp deck corners was about 40 percent greater than the coefficient for the hull with rounded deck corners.

The evidence seems fairly conclusive that, in float and hull design, an attempt should be made to eliminate adverse pressure gradients tending to cause flow across chines. This measure is especially important in the bow sections where the air should be caused to accelerate symmetrically with respect to any sharp line. Since such a condition can be obtained for only one pitch angle, all unnecessary sharp corners should be eliminated.

Cross-chine flow can be minimized by reducing the angular setting of the float relative to the wing or by designing the float with a low natural inclination of the chines relative to the longitudinal axis. The problem is complicated by the fact that these two factors are interrelated and also by the fact that no generally accepted rules exist which determine the proper setting of the float. Both of these methods of reducing cross-chine flow must be subordinated to seaworthiness requirements. The second method, designing the float with a low natural inclination of the chines, is exemplified in the design of float 51-D and its effectiveness is shown in figure 20. Moderately inclined chines, well-rounded deck lines, a broad beam, a step, and a pointed, elevated afterbody seem to be the best compromise of a good float design from both aerodynamic and hydrodynamic considerations.

CONCLUSIONS

1. Consideration of the factors that should affect the design of outboard floats indicates that:

(a) Any design must be a succession of compromises between the most desirable features.

(b) Tank tests of a very large number of models of outboard floats do not appear to be warranted as tests of a relatively small number of fundamental types should indicate trends with sufficient accuracy.

(c) The application of tank data is limited by the lack of data as to design requirements for the conditions encountered when the seaplane is under way.

2. The tank data from the present tests indicate that:

(a) For minimum spray from the float or angle of heel of the seaplane, the planing surface of the float should have a wide stern and a low dead rise.

(b) The inclusion of a step, or other equivalent discontinuity, with a properly formed afterbody allows the use of a wide planing surface without sacrificing performance in the drifting condition.

(c) The greatest structural loads will be obtained from the float with the most effective planing surface.

3. The wind-tunnel data from the present tests indicate that:

(a) The float that may be set with its chines most nearly in line with the direction of flight in cruising is likely to be the best float from considerations of air drag.

(b) All chines or other sharp intersections in the

cross section should be avoided except where they are definitely necessary for hydrodynamic reasons.

(c) In order to obtain low air drag, it is desirable that the angle of float setting be as small as practicable.

Langley Memorial Aeronautical Laboratory,
National Advisory Committee for Aeronautics,
Langley Field, Va., October 18, 1938.

REFERENCES

1. Truscott, Starr: The N.A.C.A. Tank - A High-Speed Towing Basin for Testing Models of Seaplane Floats. T.R. No. 470, N.A.C.A., 1933.

2. Allison, John M.: Tank Tests of a Model of the Hull of the Navy PB-1 Flying Boat - N.A.C.A. Model 52. T.N. No. 576, N.A.C.A., 1936.

3. Weick, Fred E., and Wood, Donald H.: The Twenty-Foot Propeller Research Tunnel of the National Advisory Committee for Aeronautics. T.R. No. 300, N.A.C.A., 1928.

4. Parkinson, John B., and Dawson, John R.: Tank Tests of N.A.C.A. Model 40 Series of Hulls for Small Flying Boats and Amphibians. T.R. No. 543, N.A.C.A, 1936.

5. Wieselsberger, C.: Air Forces Exerted on Streamlined Bodies with Round or Square Cross-Sections, When Placed Obliquely to the Airstream. T.M. No. 267, N.A.C.A., 1924.

6. Hartman, Edwin P.: The Aerodynamic Drag of Flying-Boat Hull Models as Measured in the N.A.C.A. 20-Foot Wind Tunnel-I. T.N. No. 525, N.A.C.A., 1935.

TABLE I

Offsets for N.A.C.A. Model 51-A Outboard Float (Inches)

Station number		F. P.	1/4	1/2	1	2	3	4	5	6	7	A. P.
Distance from F. P		0.00	1.125	2.25	4.50	9.00	13.50	18.00	22.50	27.00	31.50	36.00
Distance from base line	Keel	.80	3.63	4.80	6.38	8.51	9.70	10.36	10.72	10.86	10.89	10.90
	Crown (st. line)	.00	.08	.16	.32	.64	.96	1.28	1.59	1.91	2.23	2.55
	Chine	.80	1.34	1.98	3.40	6.21	8.07	9.19	9.85	10.20	10.52	10.90
	Deck line	.00	.72	1.04	1.47	2.01	2.39	2.65	2.79	2.88	2.85	2.55
Half-breadths	Deck and chine	.00	2.19	3.06	4.07	4.99	5.22	4.99	4.36	3.41	2.11	.00

TABLE II

Offsets for N.A.C.A. Model 51-B Outboard Float (Inches)

Station number		F.P.	1/4	1/2	1	2	3	4	5	6	7	8	A.P.
Distance from F.P.		0.00	1.00	2.00	4.00	8.00	12.00	16.00	20.00	24.00	28.00	32.00	36.00
Distance from base line	Crown	3.28	1.17	.62	.09	.03	.25	.75	1.42	2.26	3.22	4.22	5.22
	Keel	3.28	5.81	6.76	8.06	9.66	10.69	11.32	11.75	12.12	12.45	12.75	13.03
	Chine	3.28	3.43	3.81	4.78	6.48	7.73	8.69	9.40	10.11	10.87	11.80	12.97
Chine half-breadths and crown radius		.00	2.27	3.14	4.14	5.05	5.30	5.17	4.80	4.19	3.31	1.97	.12

TABLE III

Offsets for N.A.C.A. Model 51-C Outboard Float (Inches)

Station number		F.P.	1/4	1/2	1	2	3	4	5	6	7	8	A.P.
Distance from F.P.		0.00	1.00	2.00	4.00	8.00	12.00	16.00	20.00	24.00	28.00	32.00	36.00
Distance from base line	Keel	3.50 tan.	6.70	7.81	9.08	10.34	10.85	10.98	10.98	10.98	10.98	10.98	10.98
	Chine	3.50	4.07	4.63	5.58	7.07	8.14	8.86	9.34	9.67	9.86	9.99	10.05
	Crown	3.50 tan.	1.60	.94	.31	.00	.34	1.08	2.19	3.62	5.31	7.09	9.00
Half-breadths, chine		.00 tan.	2.27	3.14	4.14	5.05	5.30	5.30	5.30	5.30	5.30	5.30	5.30
Crown radius			2.27	3.14	4.14	5.05	5.30	5.30	5.30	5.30	5.36	6.29	13.90

TABLE IV - Offsets for N.A.C.A. Model 51-D Outboard Float (Inches)

	Station number	F.P.	1	2	3	4	5	6	7	S,F.	S,A.	9	10	A.P.
Distance from F. P.		0.00	1.49	2.97	5.94	8.91	11.88	17.82	23.76	29.70	29.70	35.64	38.61	41.58
Distance from base line	Keel	7.67	4.95	3.77	2.29	1.52	.99	.37	.09	.00	.68	Straight line		2.77
	[1] B1 1.485		6.44	5.20	3.59	2.60	1.92	1.24	.93	.68	1.30	2.41	2.97	
	B2 2.97			6.00	4.58	3.53	2.72	1.92	1.55	1.27	2.04	3.09		
	B3 4.455				4.89	3.96	3.22	2.35	1.98	1.67	2.60			
	Chine	7.67	6.87	6.19	5.01	4.15	3.40	2.60	2.10	1.80	2.72	3.22	3.34	2.77
	Side			6.56	6.50	6.44	6.37	6.25	6.13	6.06	6.06	6.00	5.94	5.94
	Deck	7.67	8.48	8.73	8.91	8.91	8.91	8.79	8.63	8.48	8.48	8.29	7.92	
	B1 1.485		8.17	8.54	8.79	8.85	8.85	8.73	8.60	8.35	8.35	7.92	6.99	
	B2 2.97			8.05	8.48	8.54	8.54	8.35	8.23	7.92	7.92	5.45		
	B3 4.455				7.18	7.67	7.74	7.61	7.12	4.52	4.52			
Half-breadths	Chine		2.85	3.84	4.89	5.51	5.75	5.82	5.82	5.82	4.70	3.34	2.35	
	[2] WL1 1.485						.74	1.86	2.79	3.53	1.86			
	WL2 2.97				.68	1.92	3.40	5.69	5.32	4.58	4.58	2.60	1.42	
	WL3 4.455			.62	2.79	5.38	5.51	5.45	5.07	4.46	4.46	3.16	2.17	
	WL4 5.94		.74	2.60	4.70	5.14	5.26	5.14	4.70	4.08	4.08	2.79	1.86	
	WL5 7.425		2.60	3.40	4.33	4.70	4.83	4.64	4.27	3.59	3.59	2.29	1.18	

[1] Distance from center line (plane of symmetry) to buttock (section of hull surface made by a vertical plane parallel to the plane of symmetry).

[2] Distance from base line to water line (section of hull surface made by a horizontal plane parallel to base line).

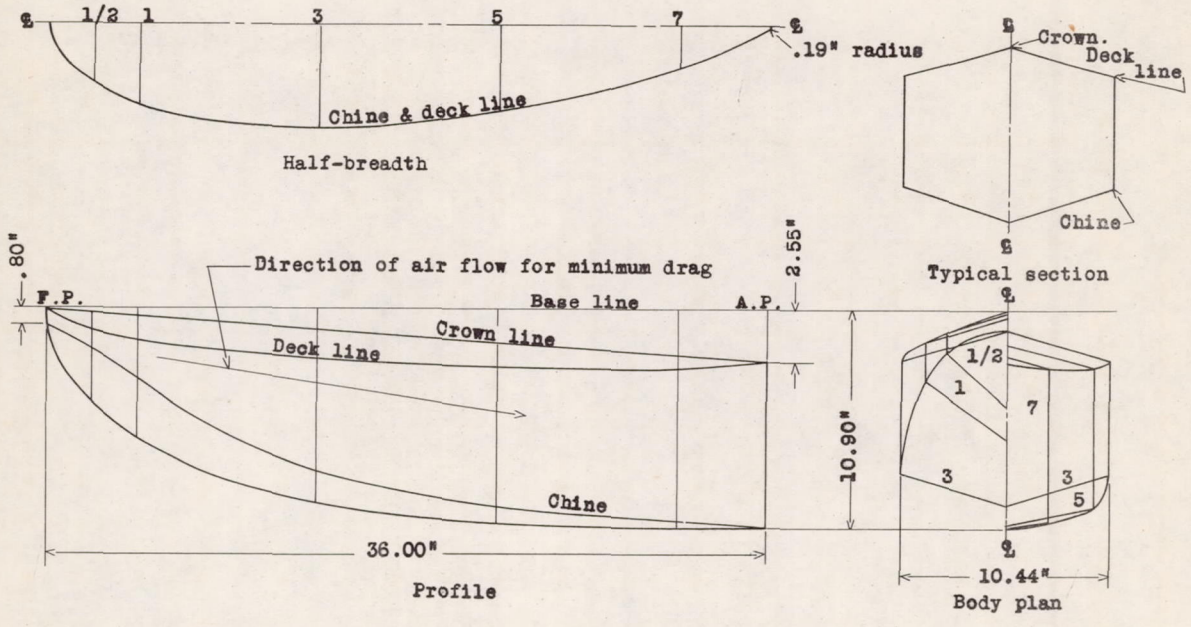


Figure 1.- Lines of N.A.C.A. Model 51-A. Volume = 1.092 cu. ft.

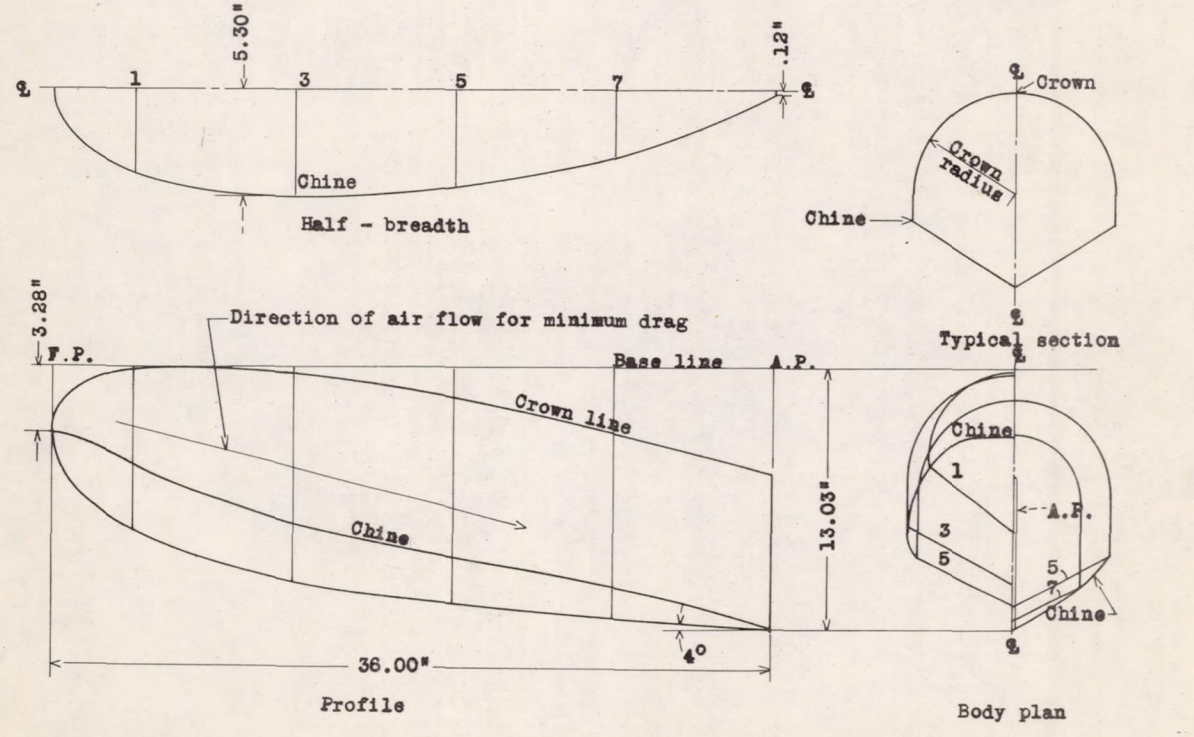


Figure 2.- Lines of N.A.C.A. Model 51-B. Volume = 1.200 cu. ft.

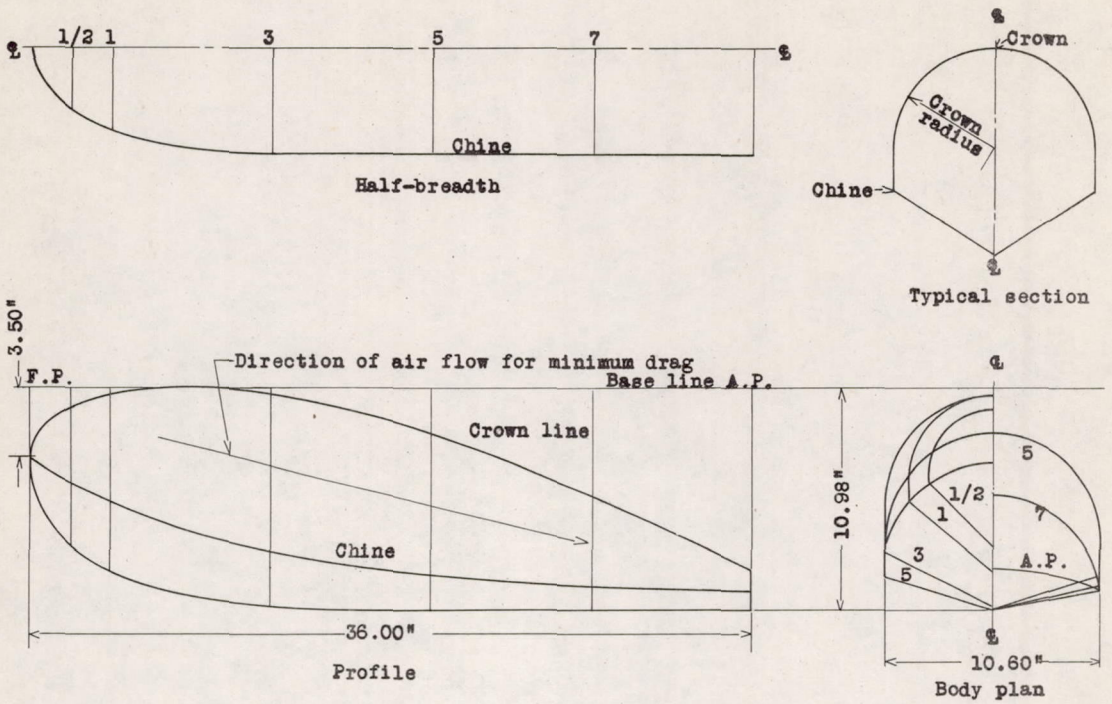


Figure 3.- Lines of N.A.C.A. Model 51-C. Volume = 1.185 cu. ft.

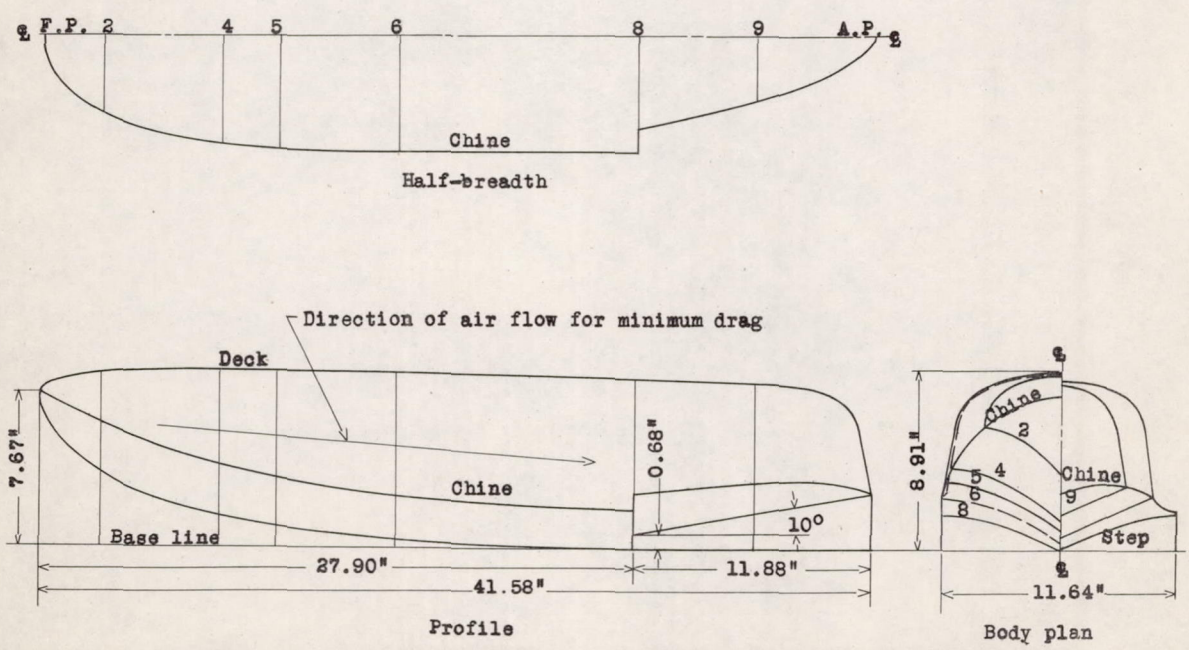


Figure 4.- Lines of N.A.C.A. Model 51-D. Volume = 1.190 cu. ft.

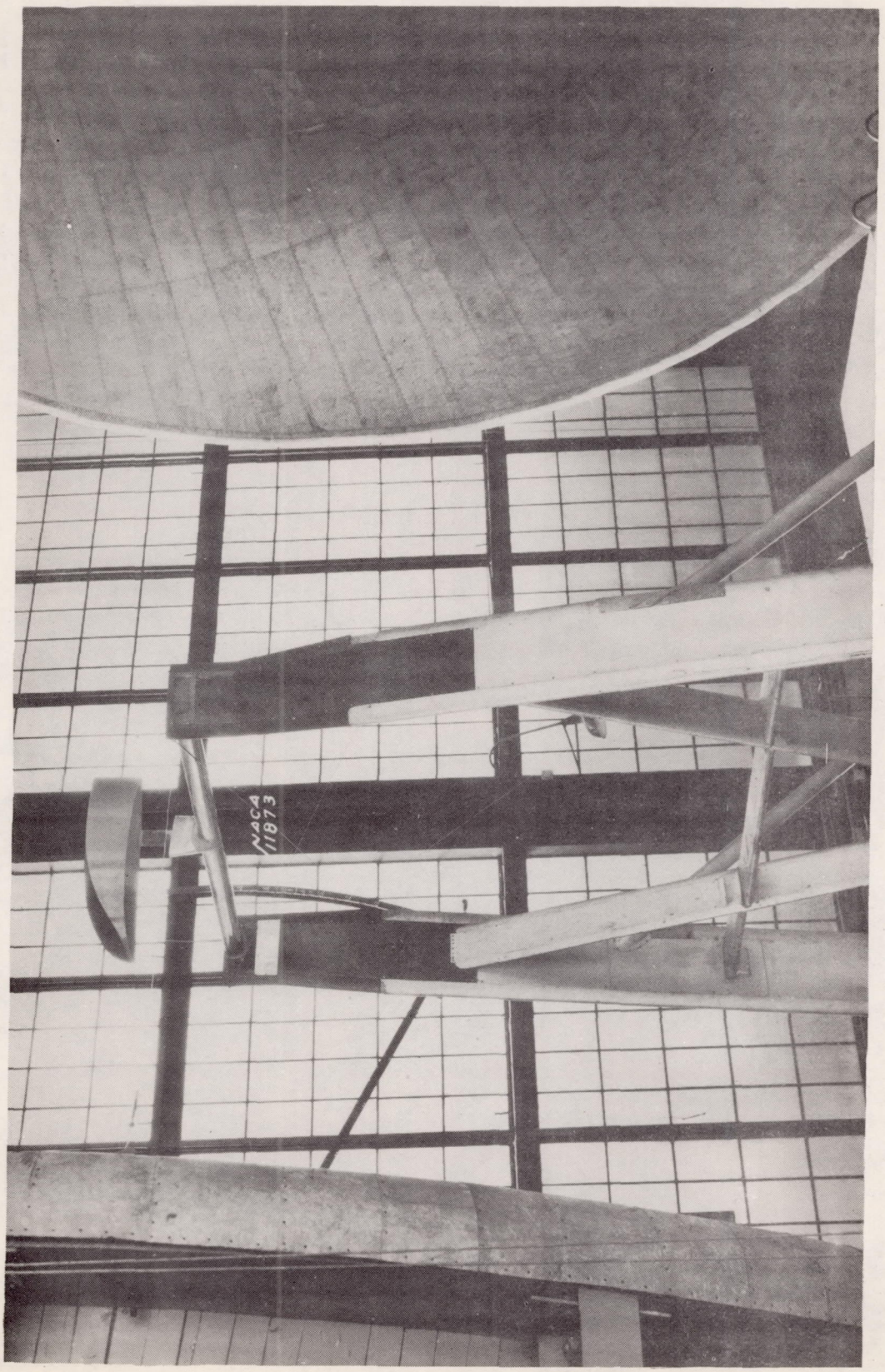


Figure No. 5.- Model 51-A mounted in wind tunnel.

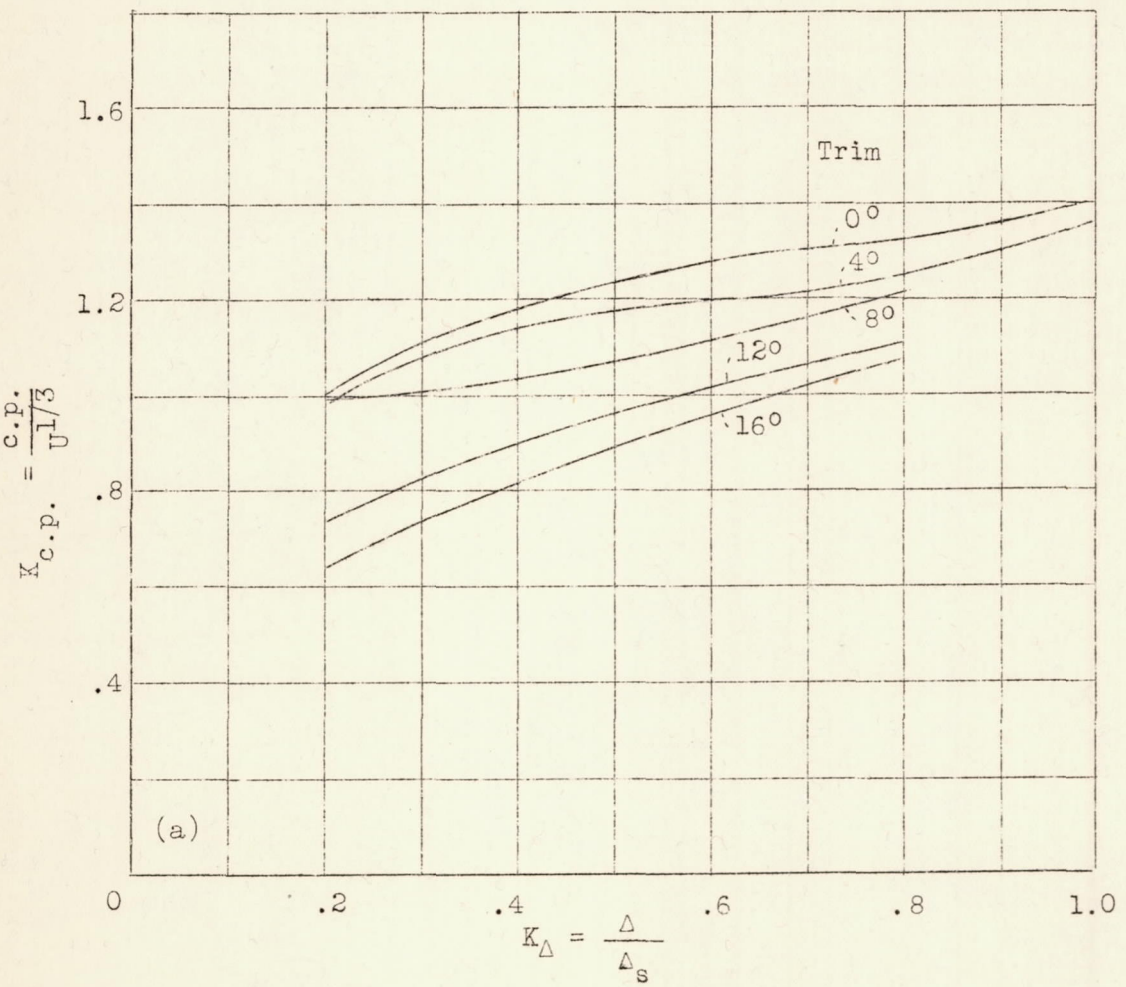


Figure 6(a).- Model 51-A. Variation of draft and center-of-pressure coefficients at rest. Center-of-pressure coefficient against load coefficient.

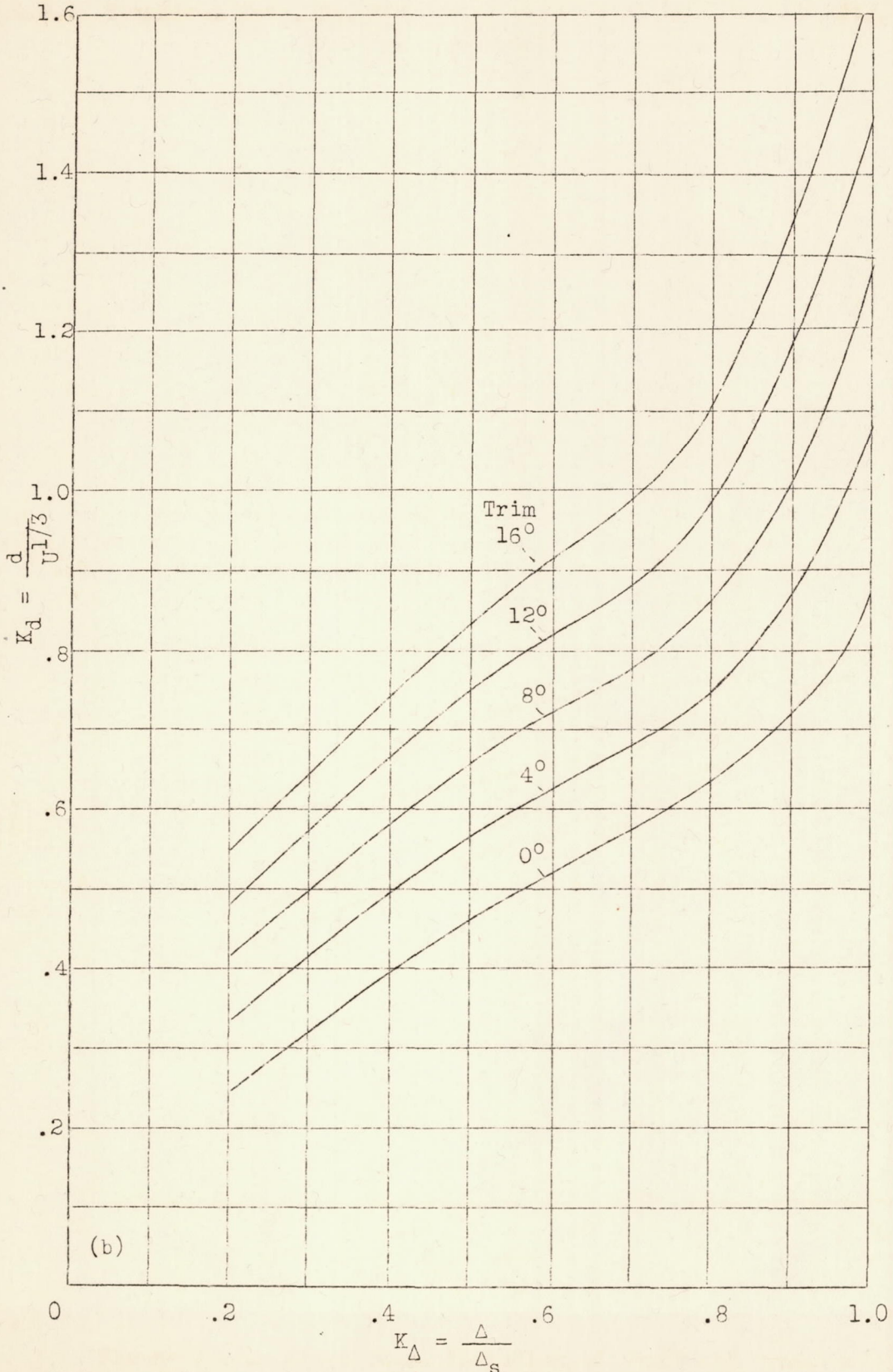


Figure 6(b).- Model 51-A. Variation of draft and center-of-pressure coefficients at rest. Draft coefficient against load coefficient.

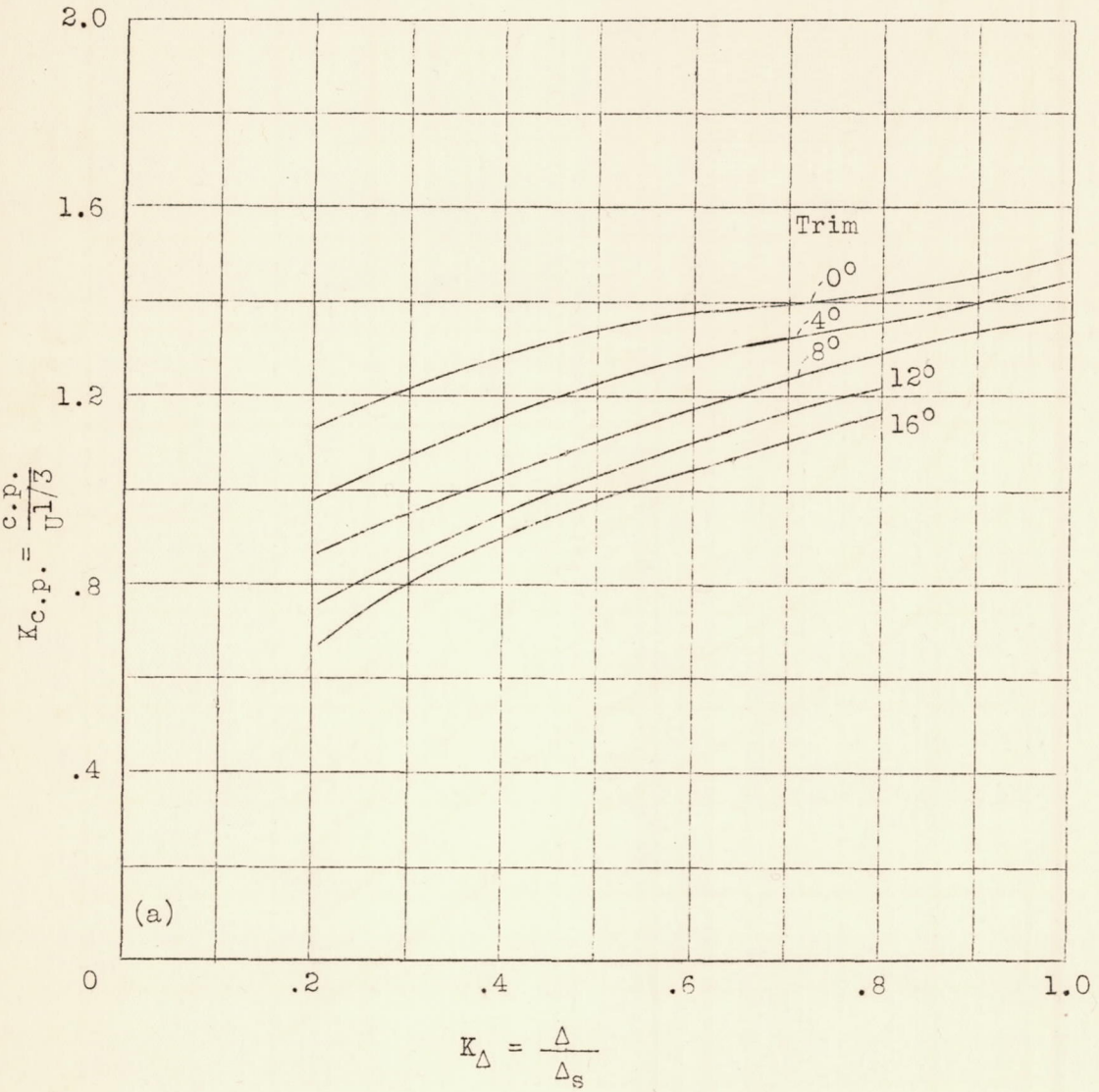


Figure 7(a).- Model 51-B. Variation of draft and center-of-pressure coefficients at rest. Center-of-pressure coefficient against load coefficient.

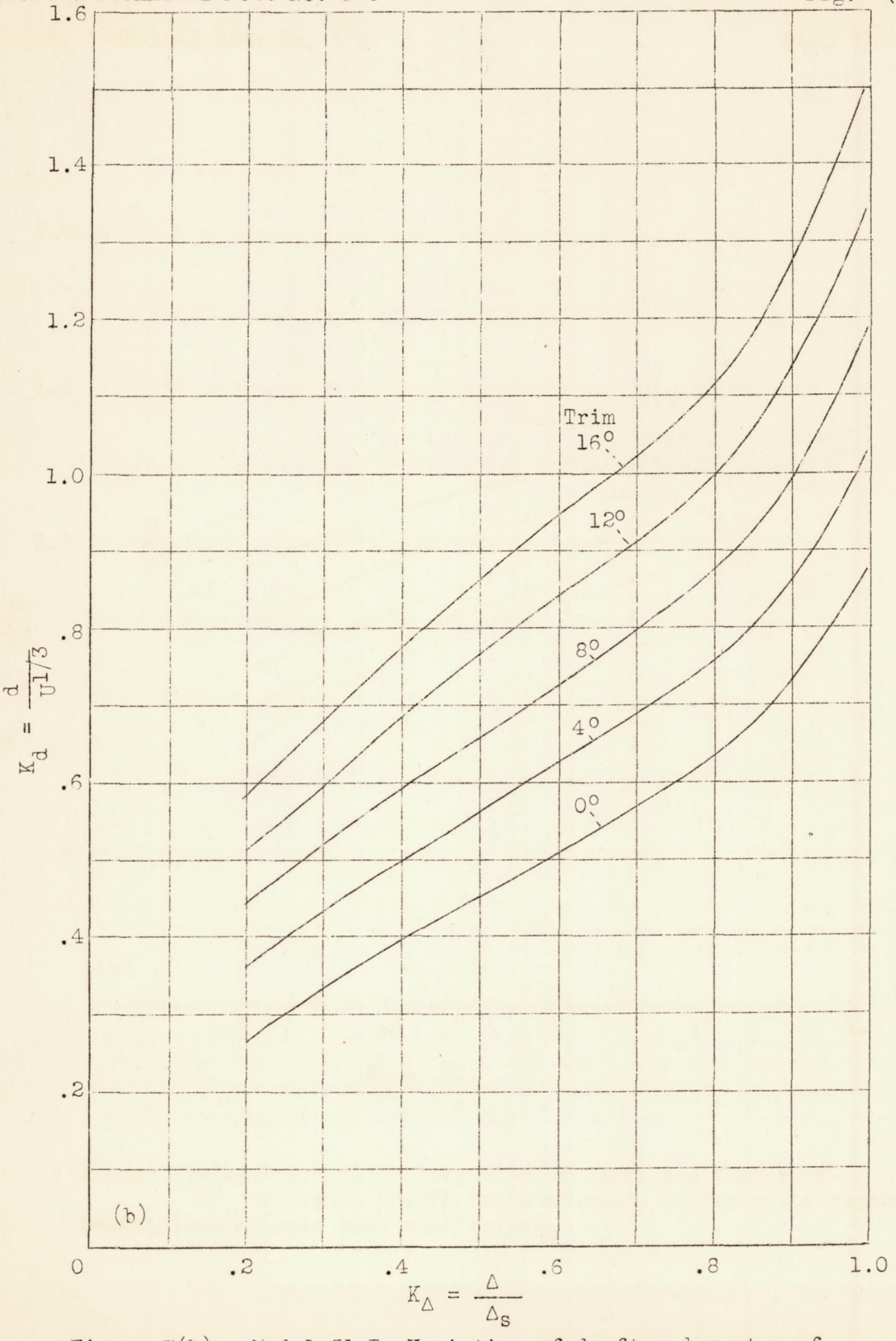


Figure 7(b).- Model 51-B. Variation of draft and center-of-pressure coefficients at rest. Draft coefficient against load coefficient.

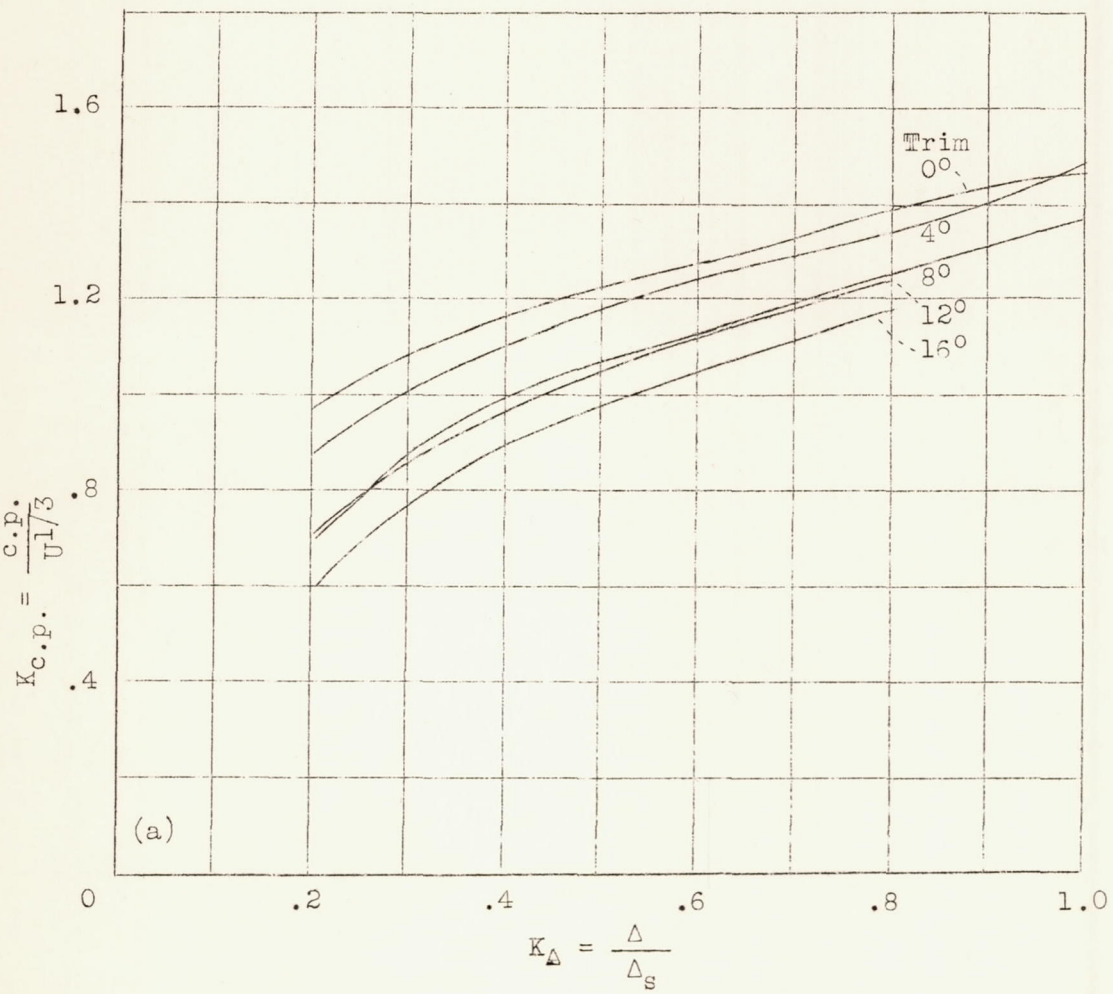


Figure 8(a).- Model 51-C. Variation of draft and center-of-pressure coefficients at rest. Center-of-pressure coefficient against load coefficient.

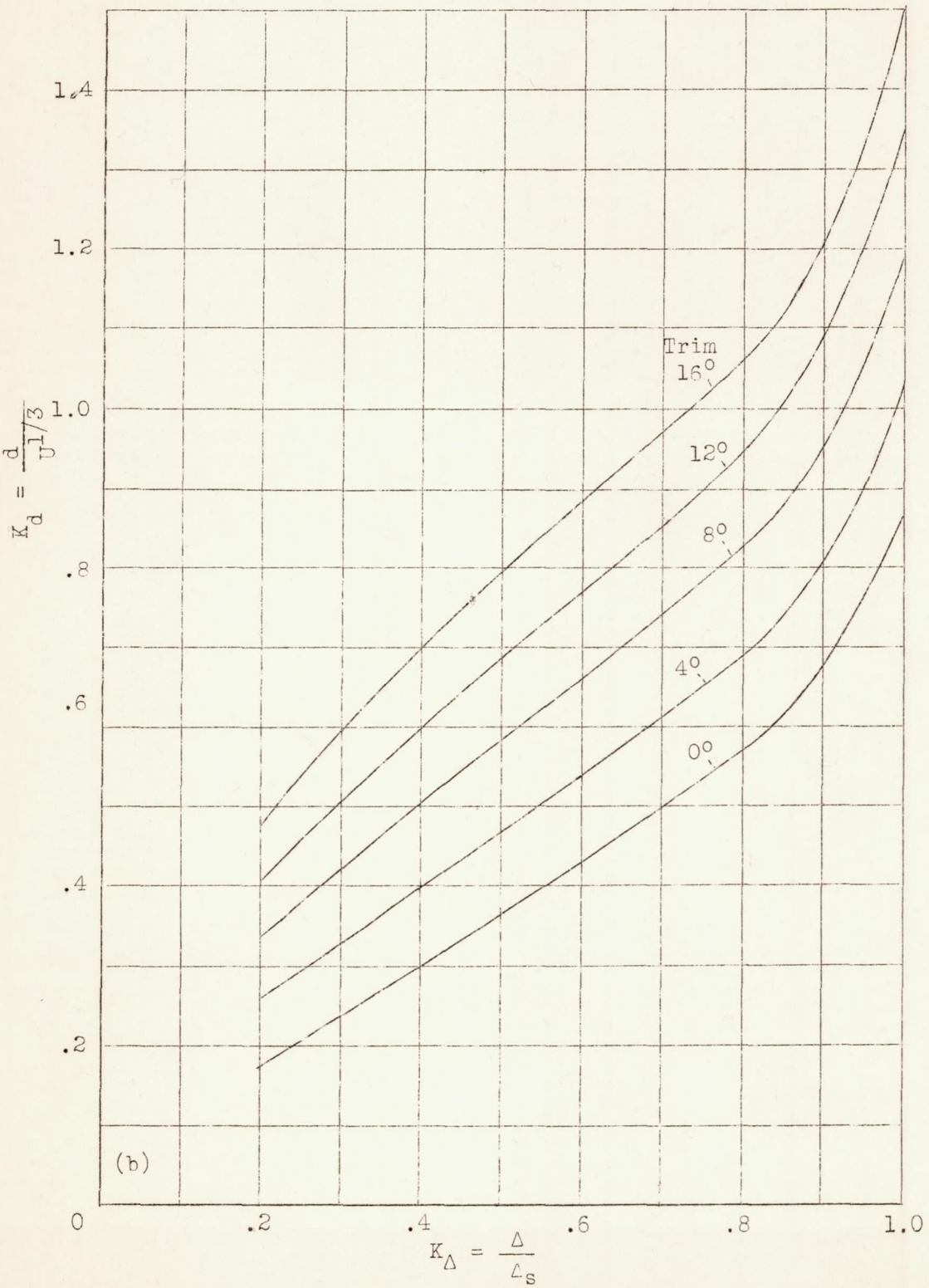


Figure 8(b).- Model 51-C. Variation of draft and center-of-pressure coefficients at rest. Draft coefficient against load coefficient.

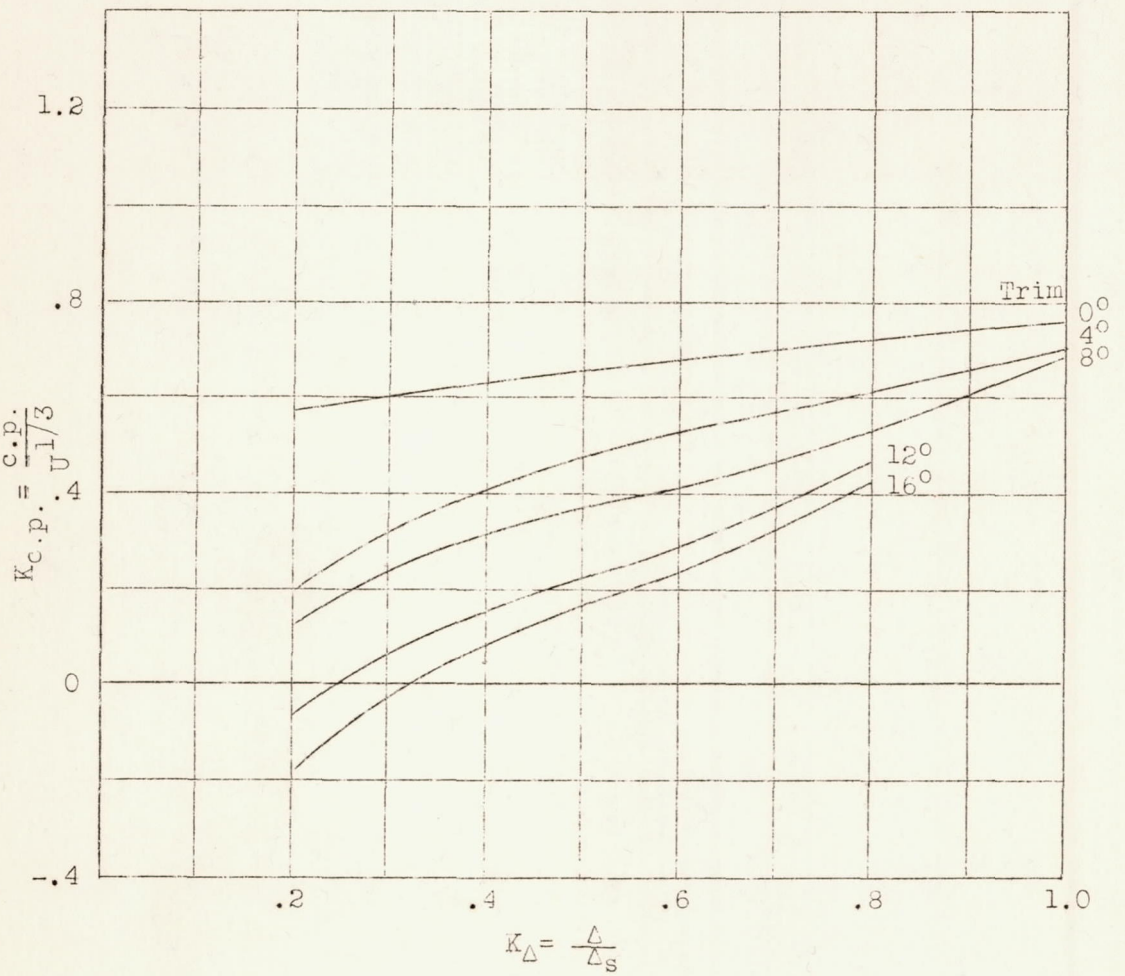


Figure 9(a).- Model 51-D. Variation of draft and center-of-pressure coefficients at rest. Center-of-pressure coefficient against load coefficient.

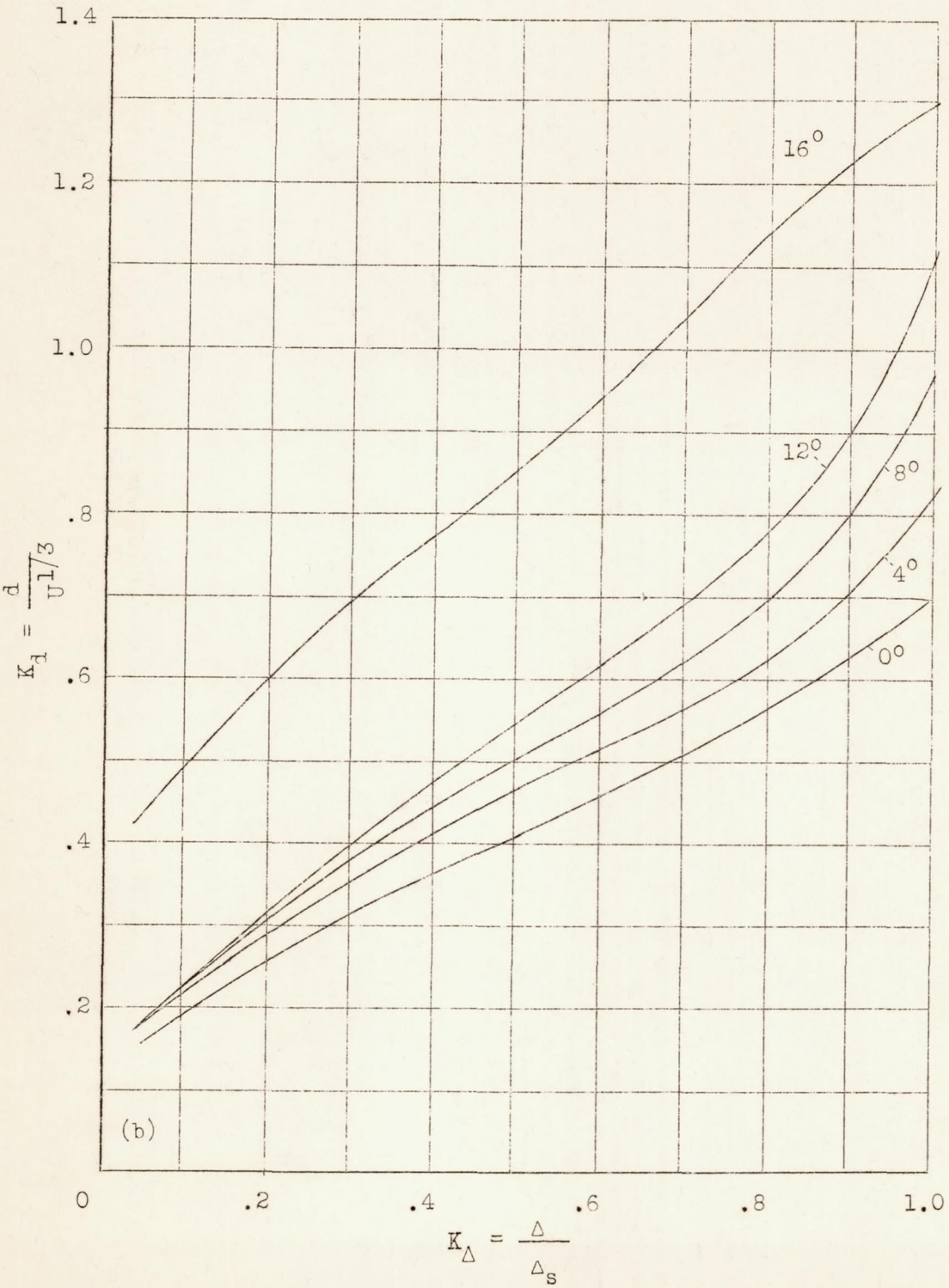


Figure 9(b).- Model 51-D. Variation of draft and center-of-pressure coefficients at rest. Draft coefficient against load coefficient.

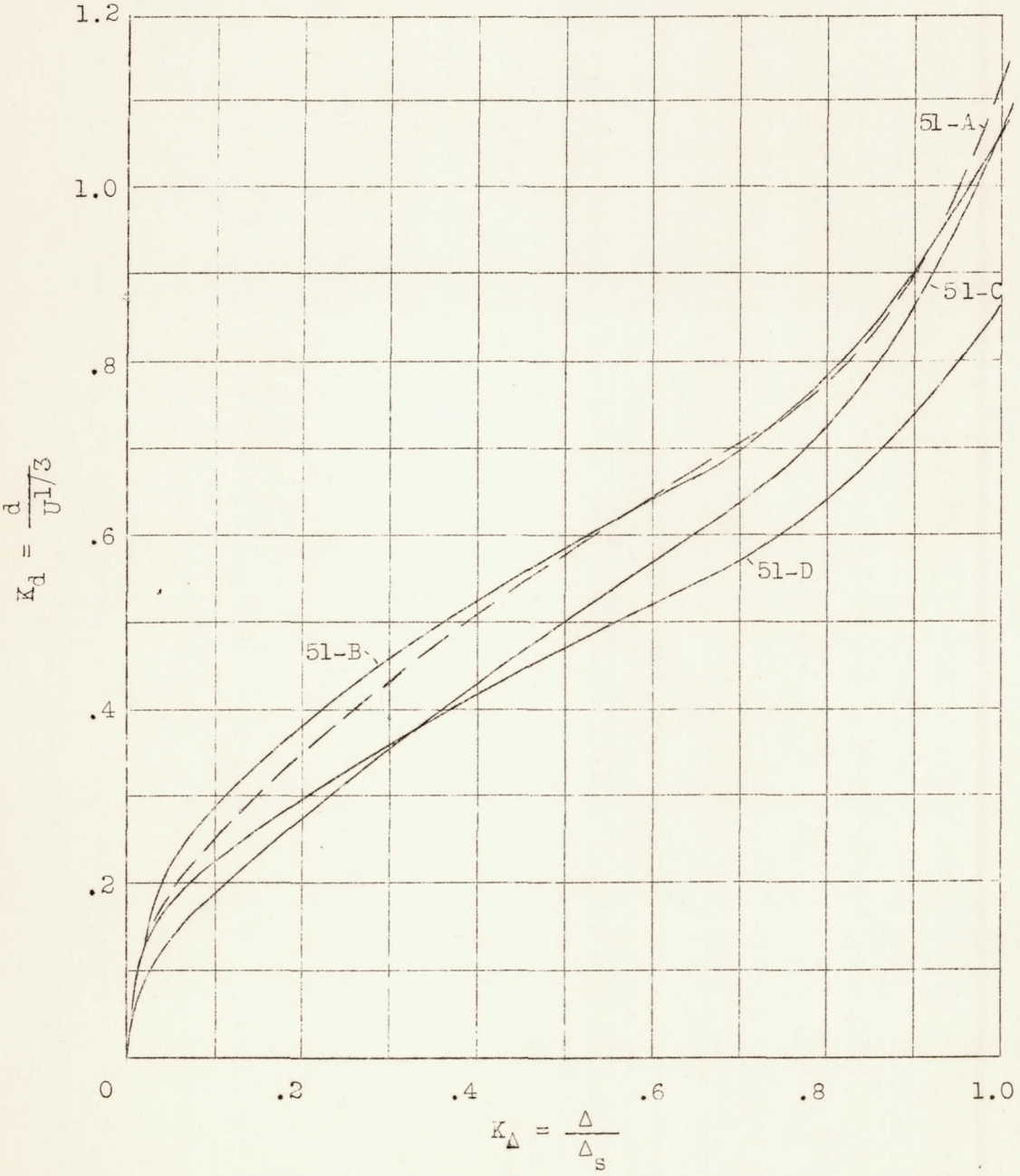


Figure 10.- Comparison of draft coefficients of models of outboard floats at rest. Trim, 5° .

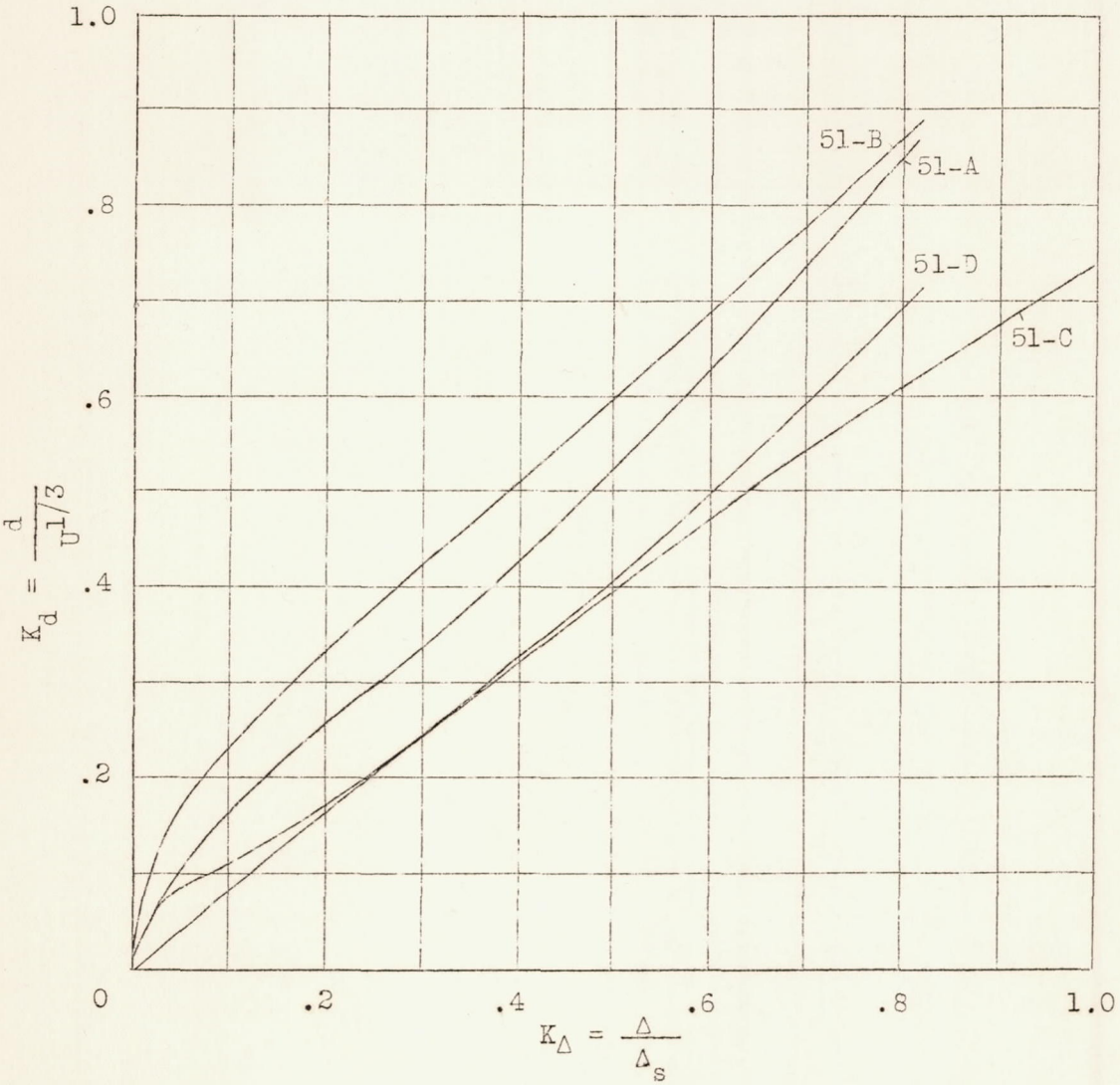


Figure 11.- Comparison of draft coefficients of models of outboard floats under way. Trim, 8° ; K_V , 2 .

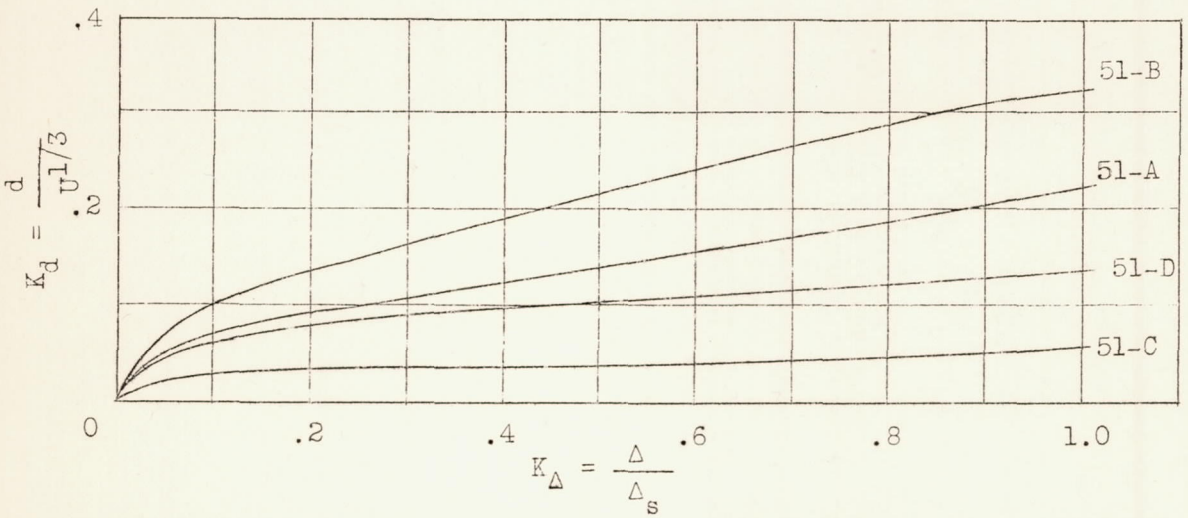


Figure 12.- Comparison of draft coefficients of models of outboard floats under way. Trim, 13° ; K_V , 5.

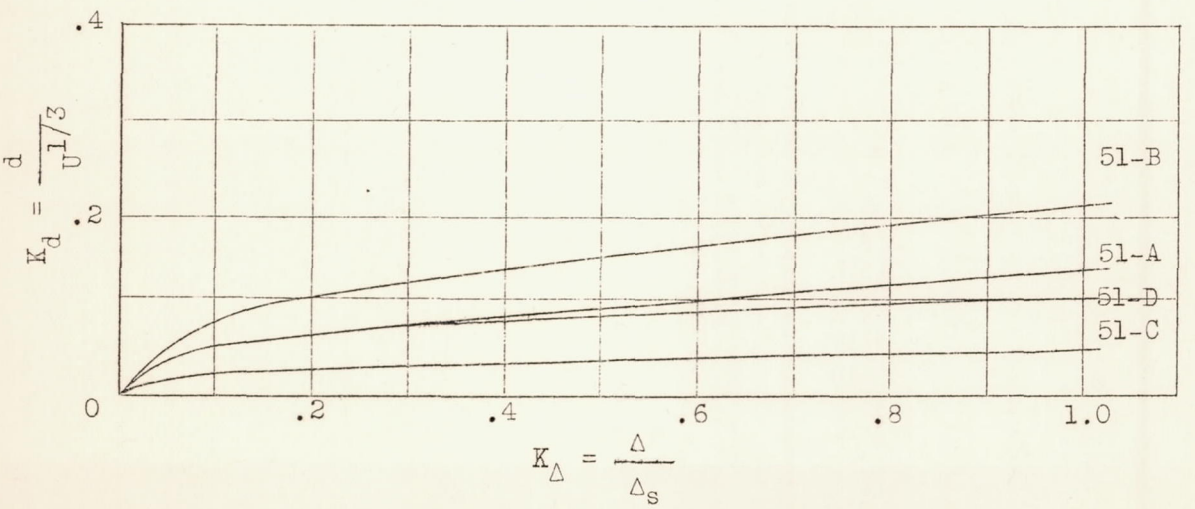


Figure 13.- Comparison of draft coefficients of models of outboard floats under way. Trim, 9° ; K_V , 8.

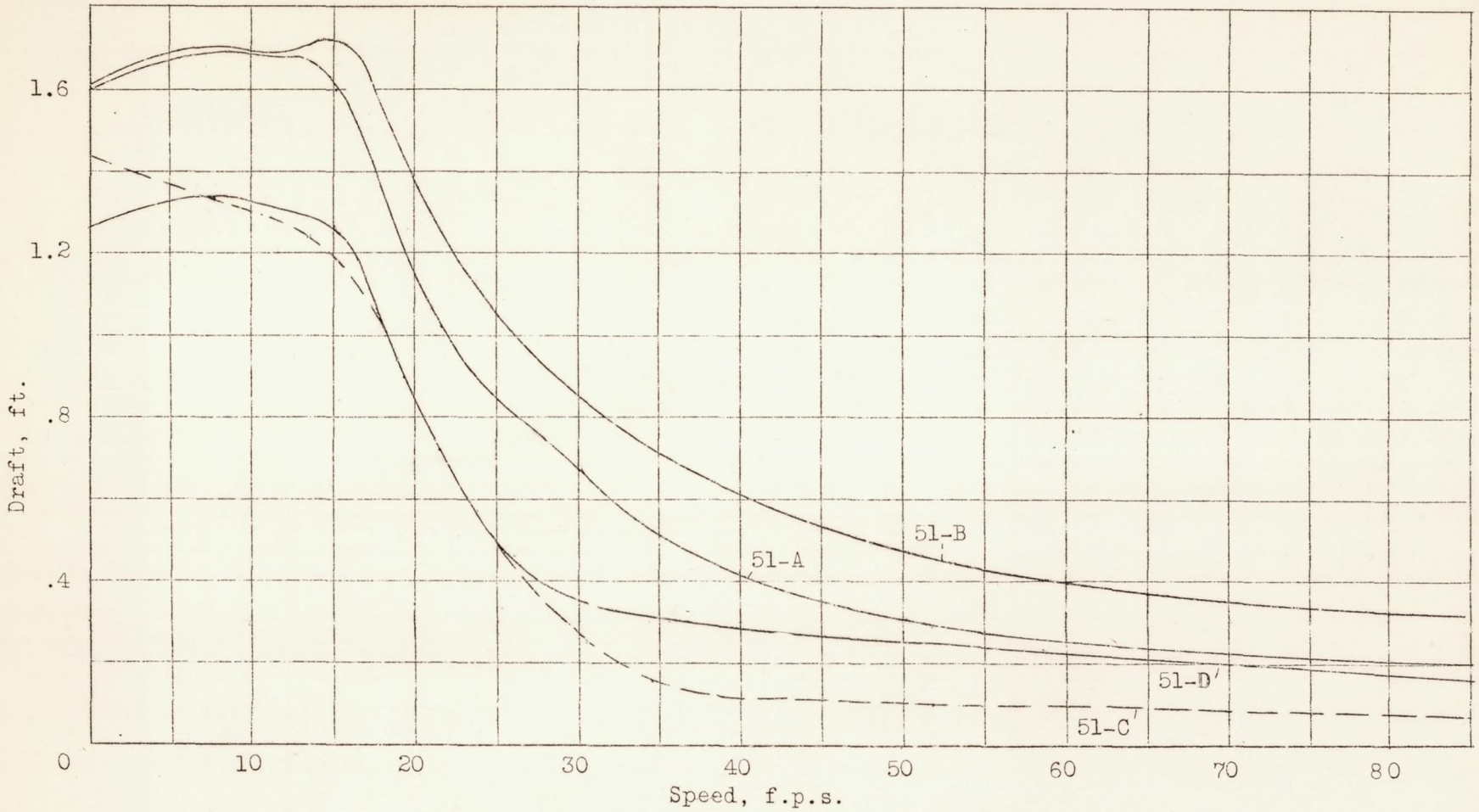


Figure 14.- Comparison of drafts of outboard floats for 8,000 pound flying boat. K_{Δ}, 0.6; Δ_s, 780 lb.

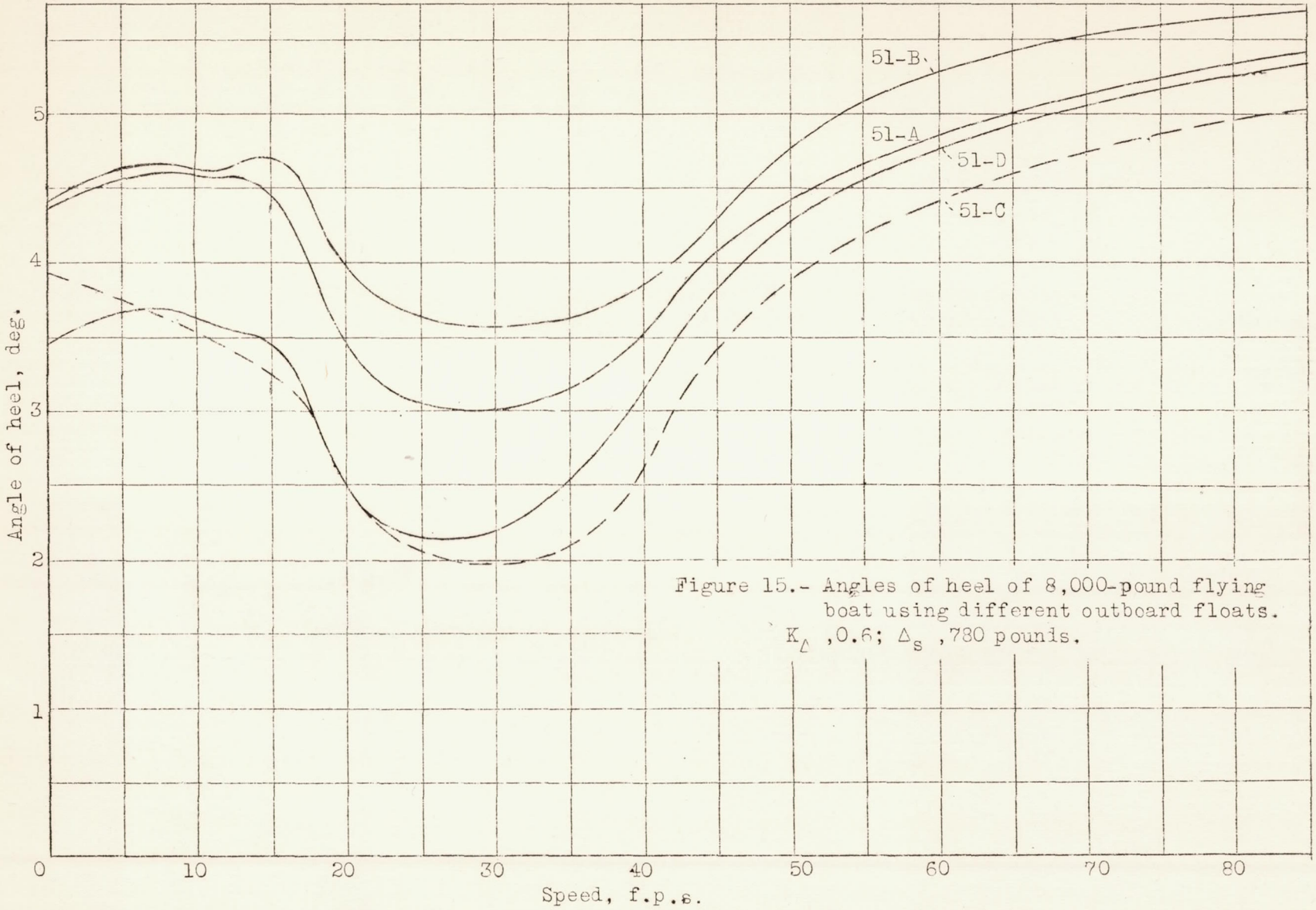


Figure 15.- Angles of heel of 8,000-pound flying boat using different outboard floats. K_{Δ} ,0.6; Δ_s ,780 pounds.

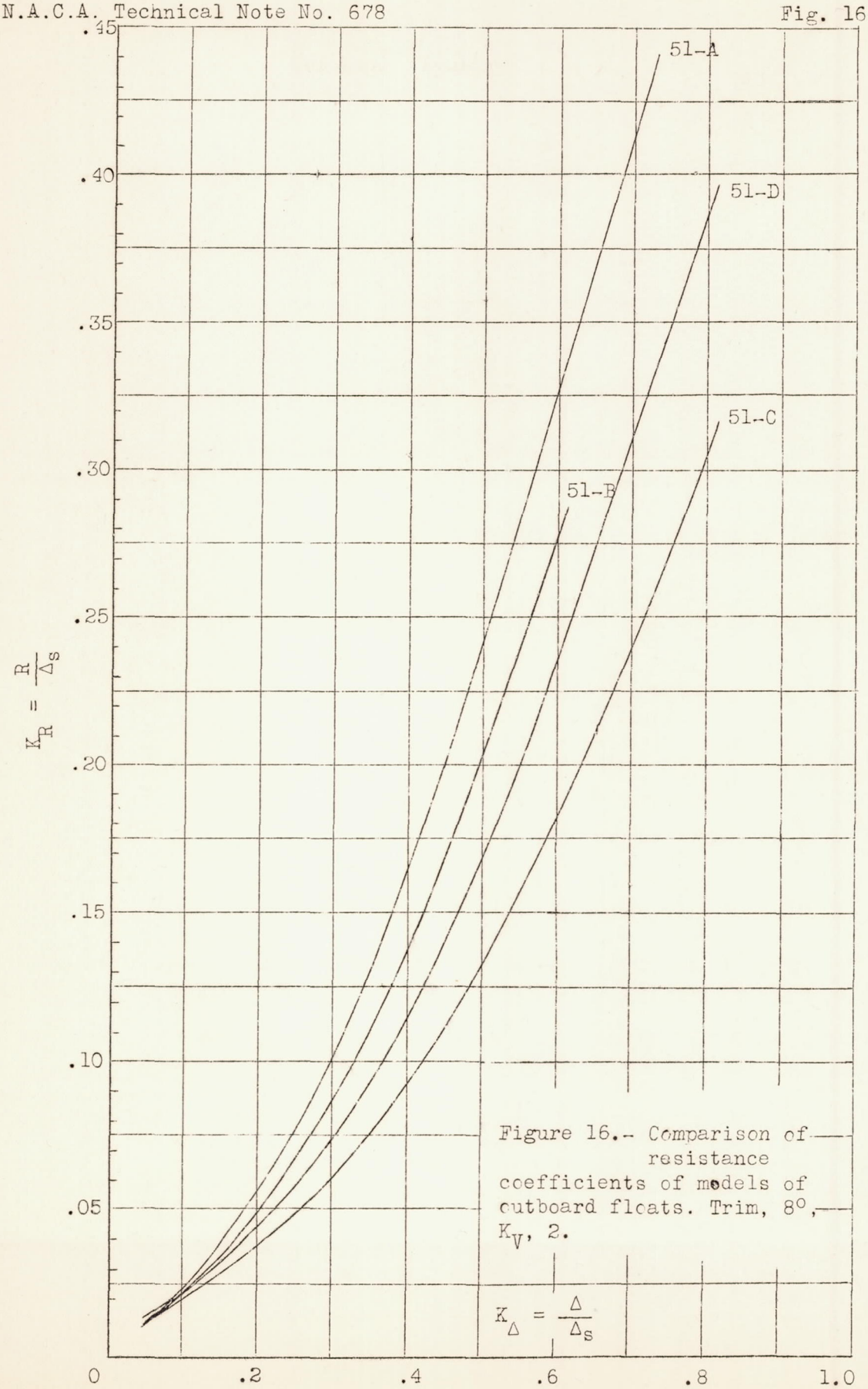


Figure 16.- Comparison of resistance coefficients of models of outboard floats. Trim, 8°, K_V, 2.

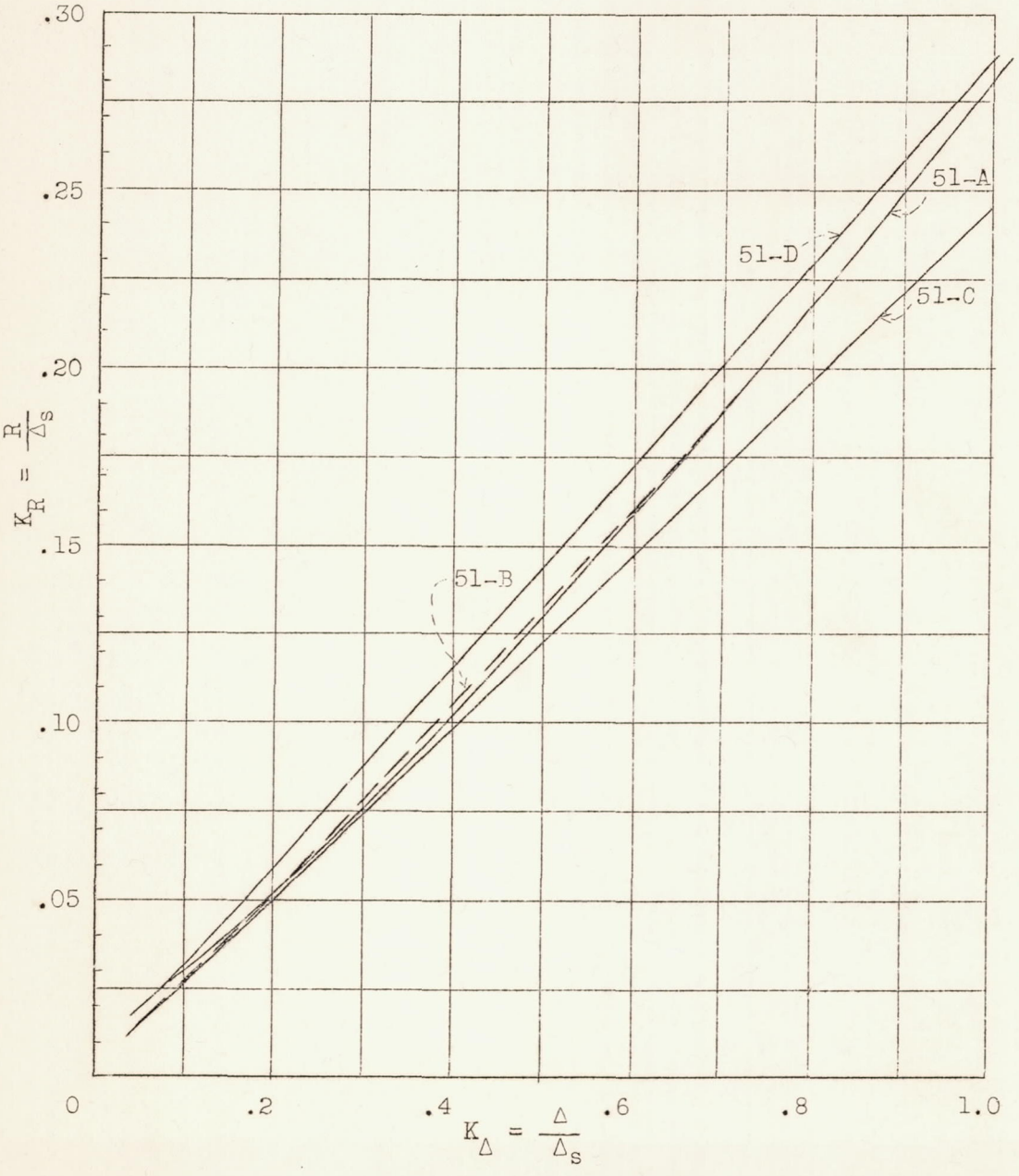


Figure 17.- Comparison of resistance coefficients of models of outboard floats. Trim, 13°; K_V, 5.

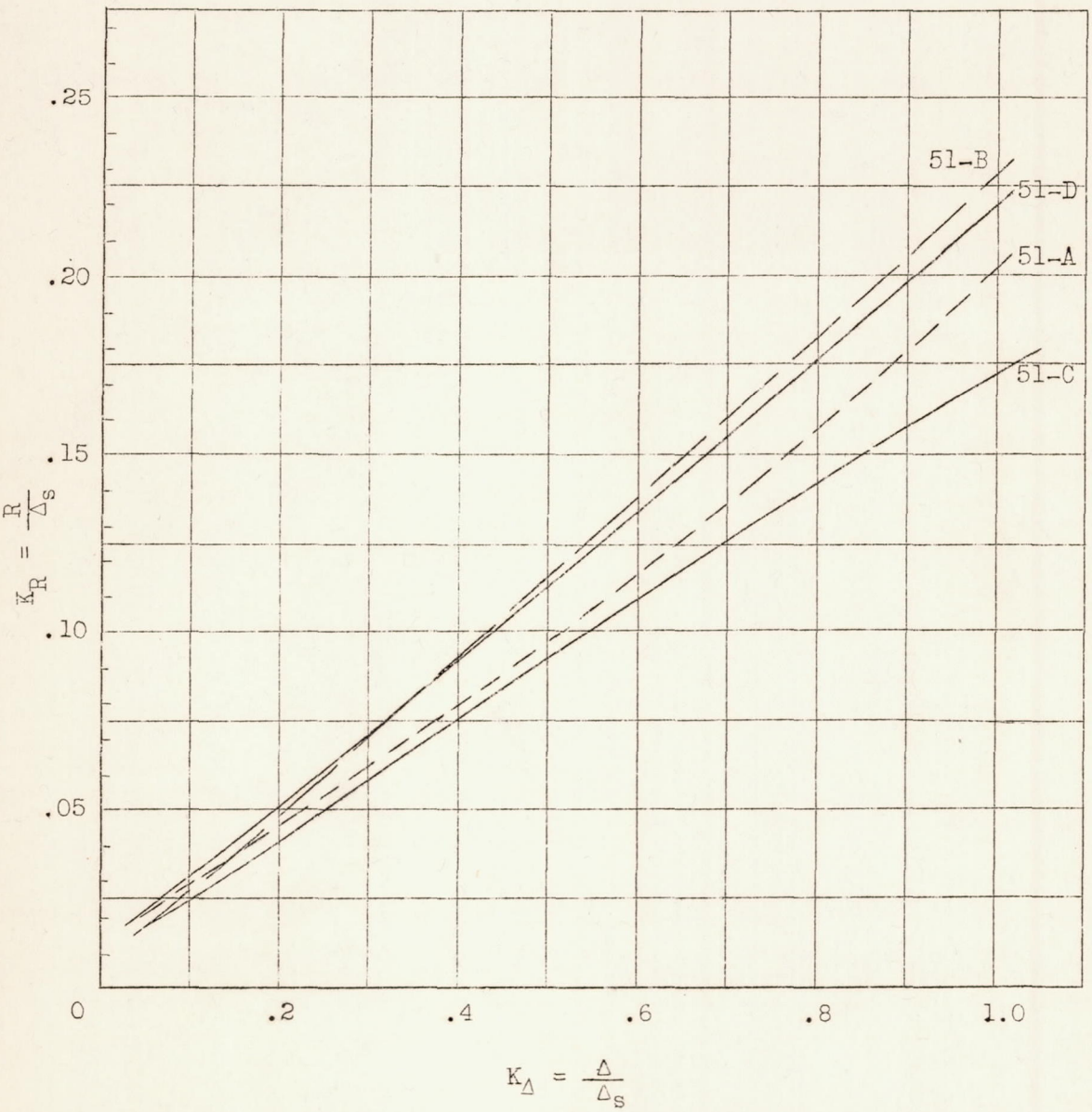


Figure 18.- Comparison of resistance coefficients of models of outboard floats. Trim, 9°; K_V, 8.

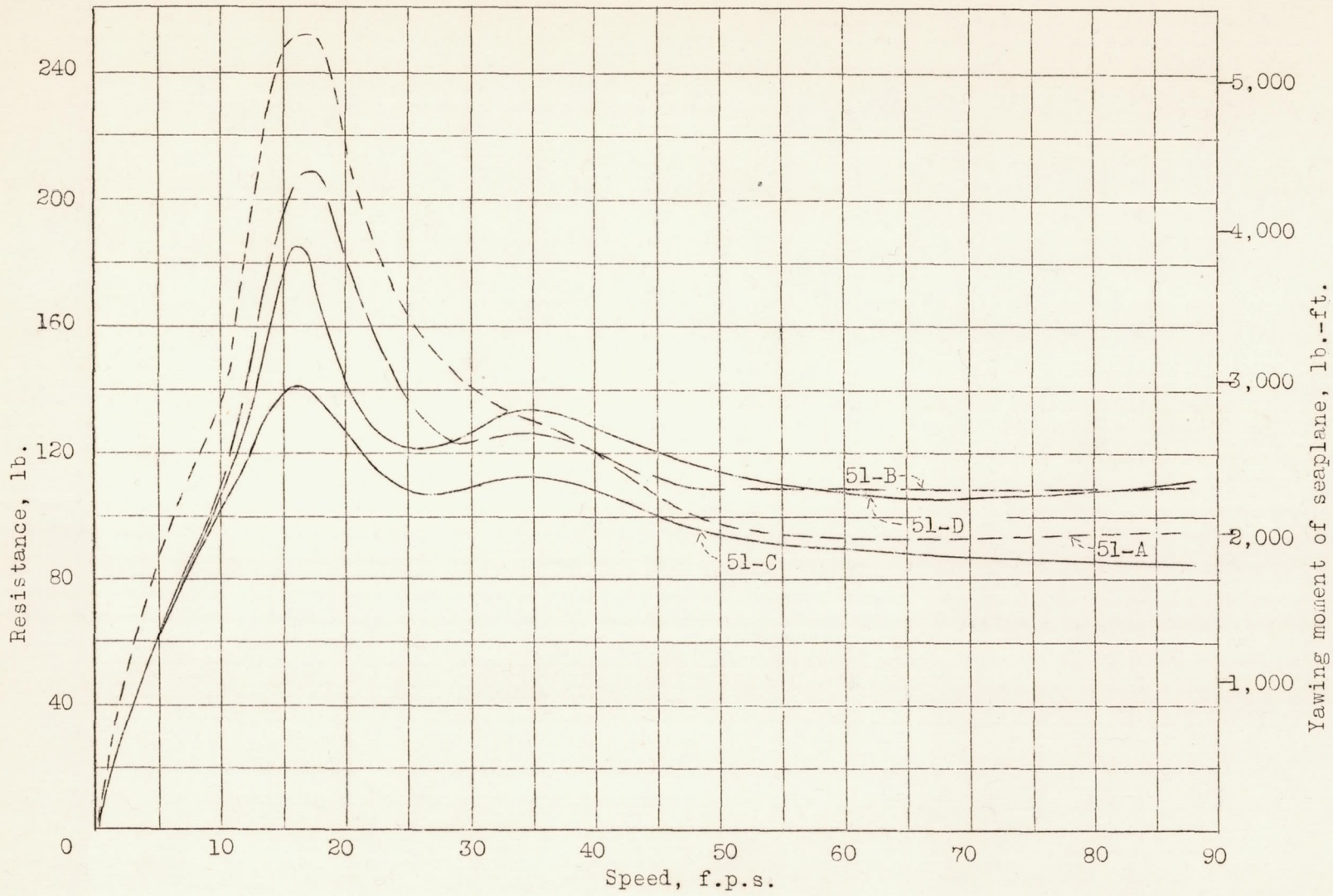


Figure 19.- Comparison of resistance of outboard floats and resulting yawing moment for 8,000-pound flying boat. K_{Δ}, 0.6, Δ_s, 780 lb.

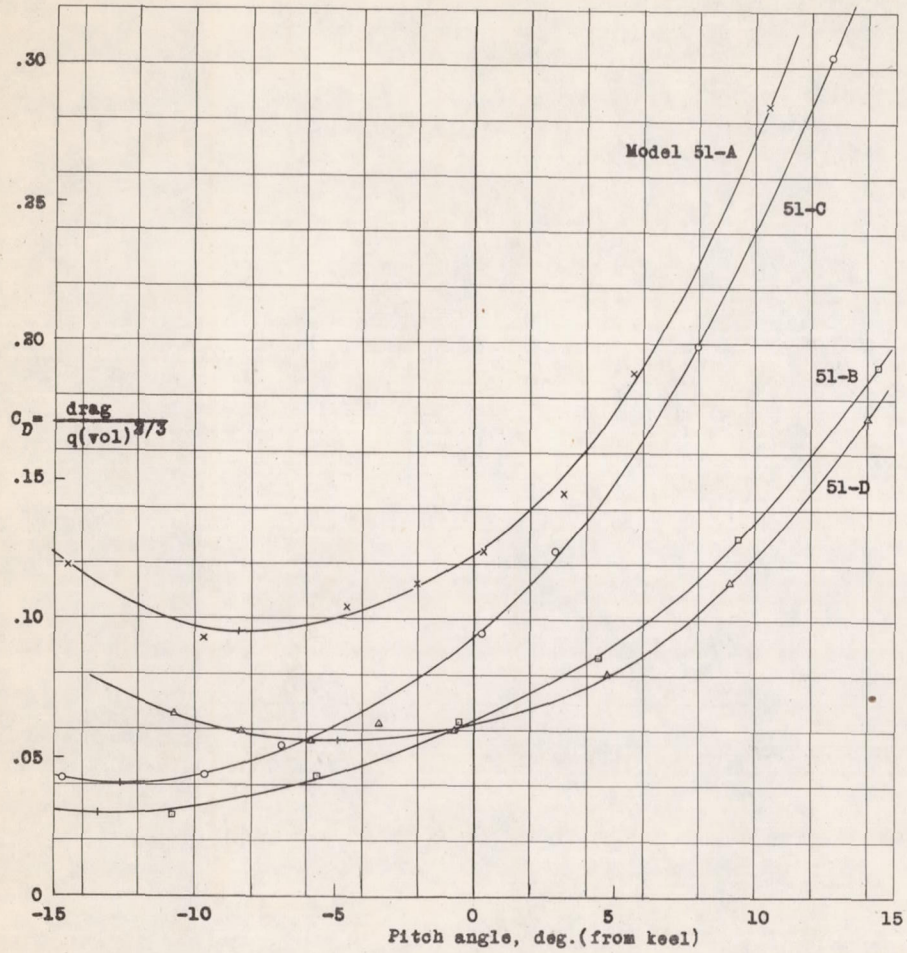


Figure 20.- Air drag characteristics of models of outboard floats.

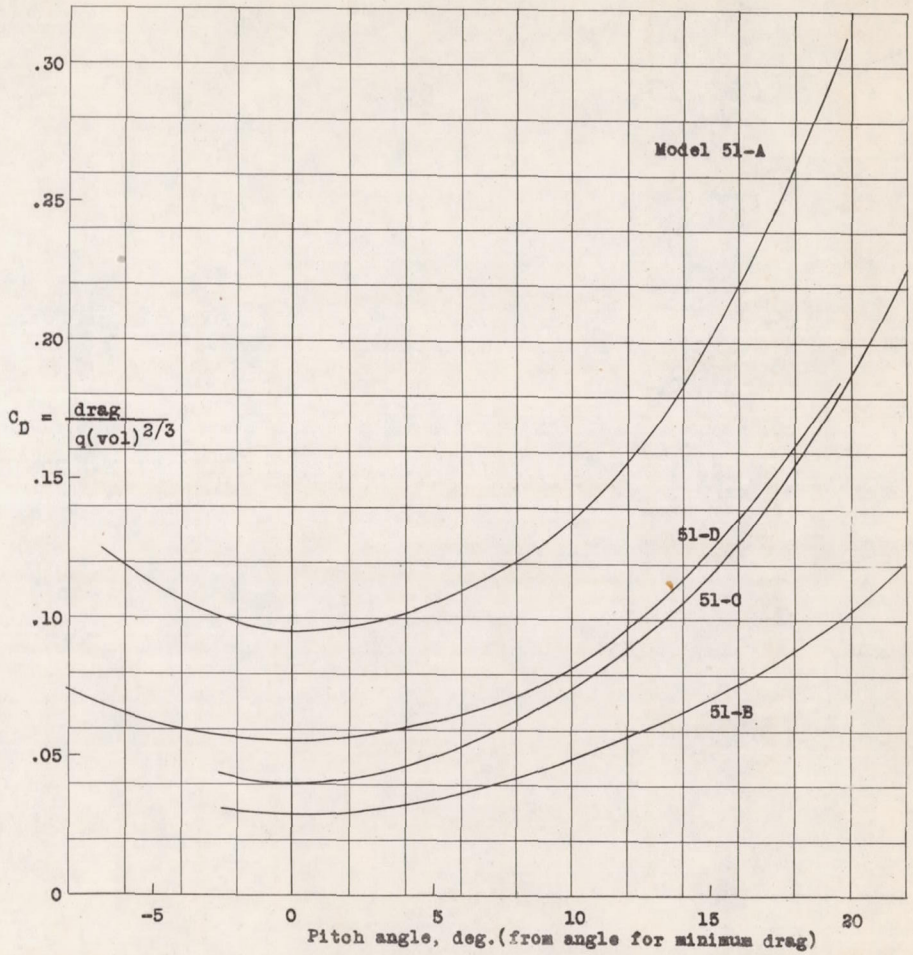
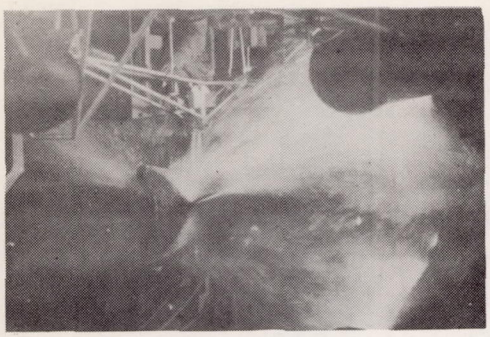
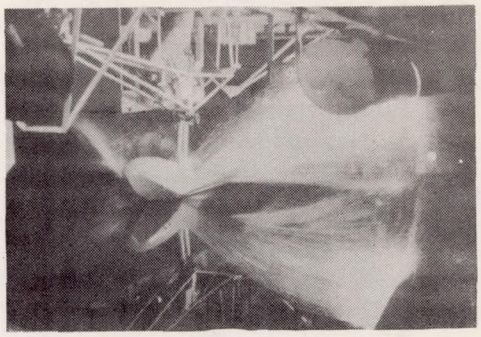


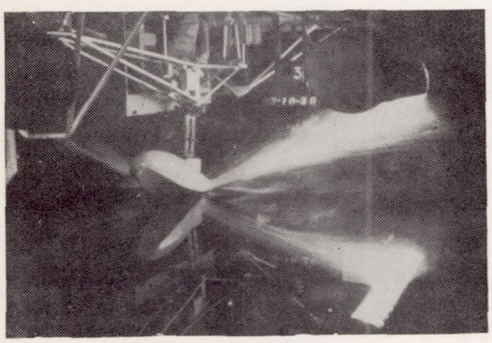
Figure 21.- Air drag characteristics of models of outboard floats.



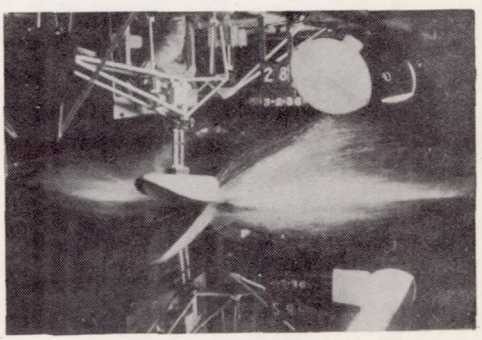
Model 51-A
$\tau = 8^{\circ}$, $K_{\Delta}=1.0$, $K_{V}=3.66$



Model 51-B
$\tau = 8^{\circ}$, $K_{\Delta}=1.0$, $K_{V}=4.24$



Model 51-C
$\tau = 8^{\circ}$, $K_{\Delta}=1.0$, $K_{V}=4.26$

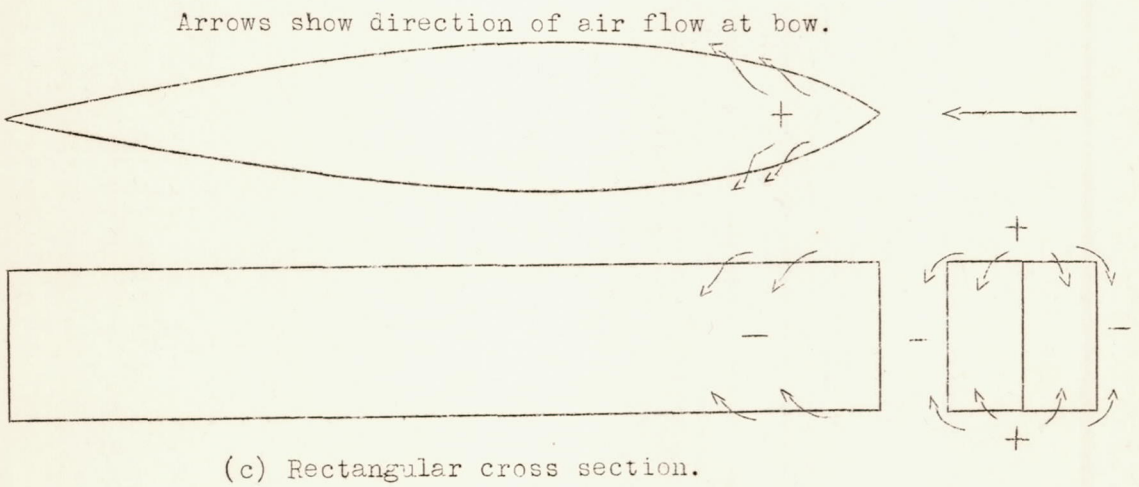


Model 51-D
$\tau = 8^{\circ}$, $K_{\Delta}=1.0$, $K_{V}=4.38$

Figure 22.- Spray photographs of models of outboard floats.

(a) Circular cross section.

(b) Square cross section.



(c) Rectangular cross section.

+positive pressure - negative pressure

Figure 23.- Streamline bodies.